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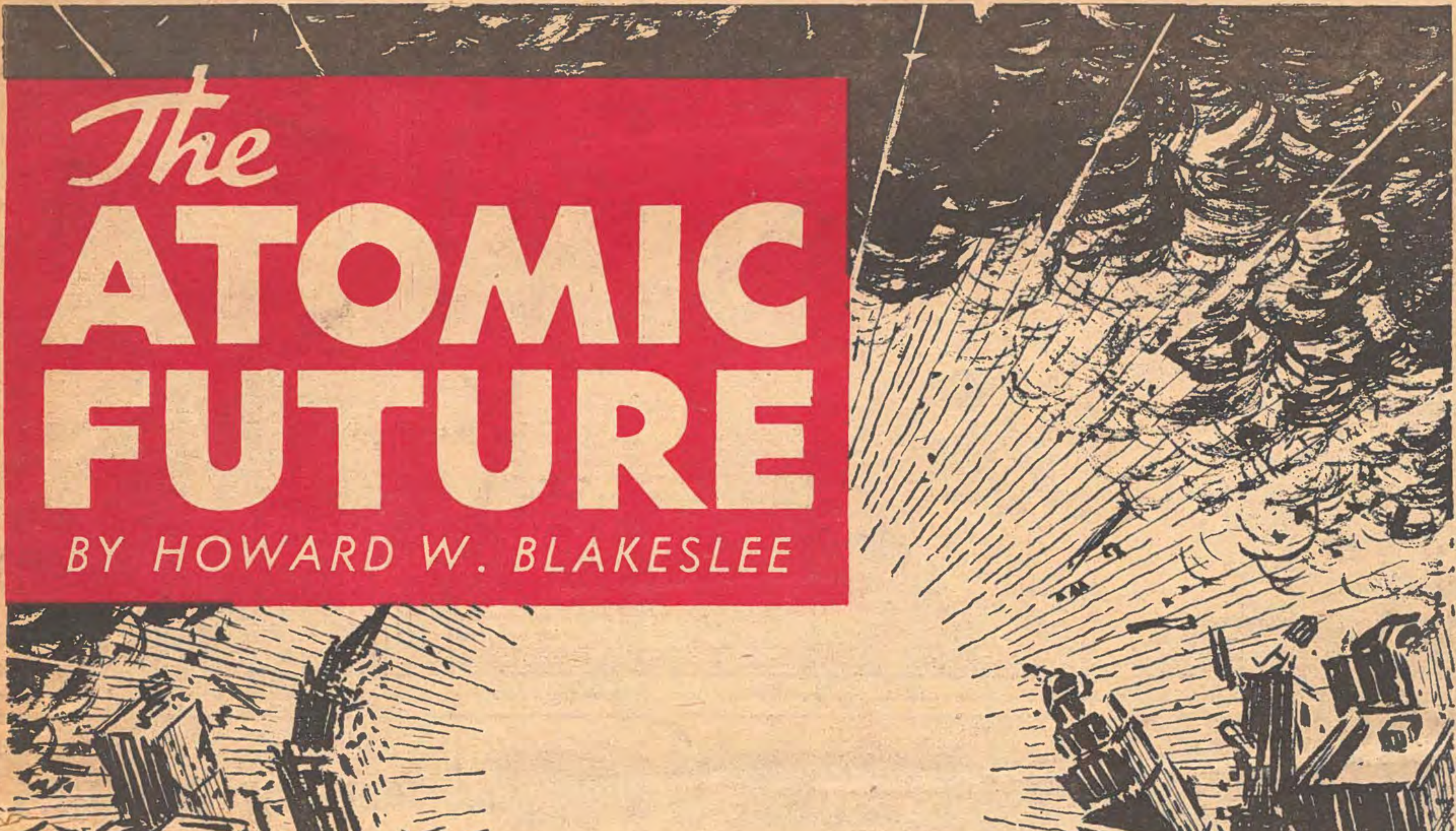
The ATOMIC FUTURE

BY HOWARD W. BLAKESLEE



PEACE

WAR

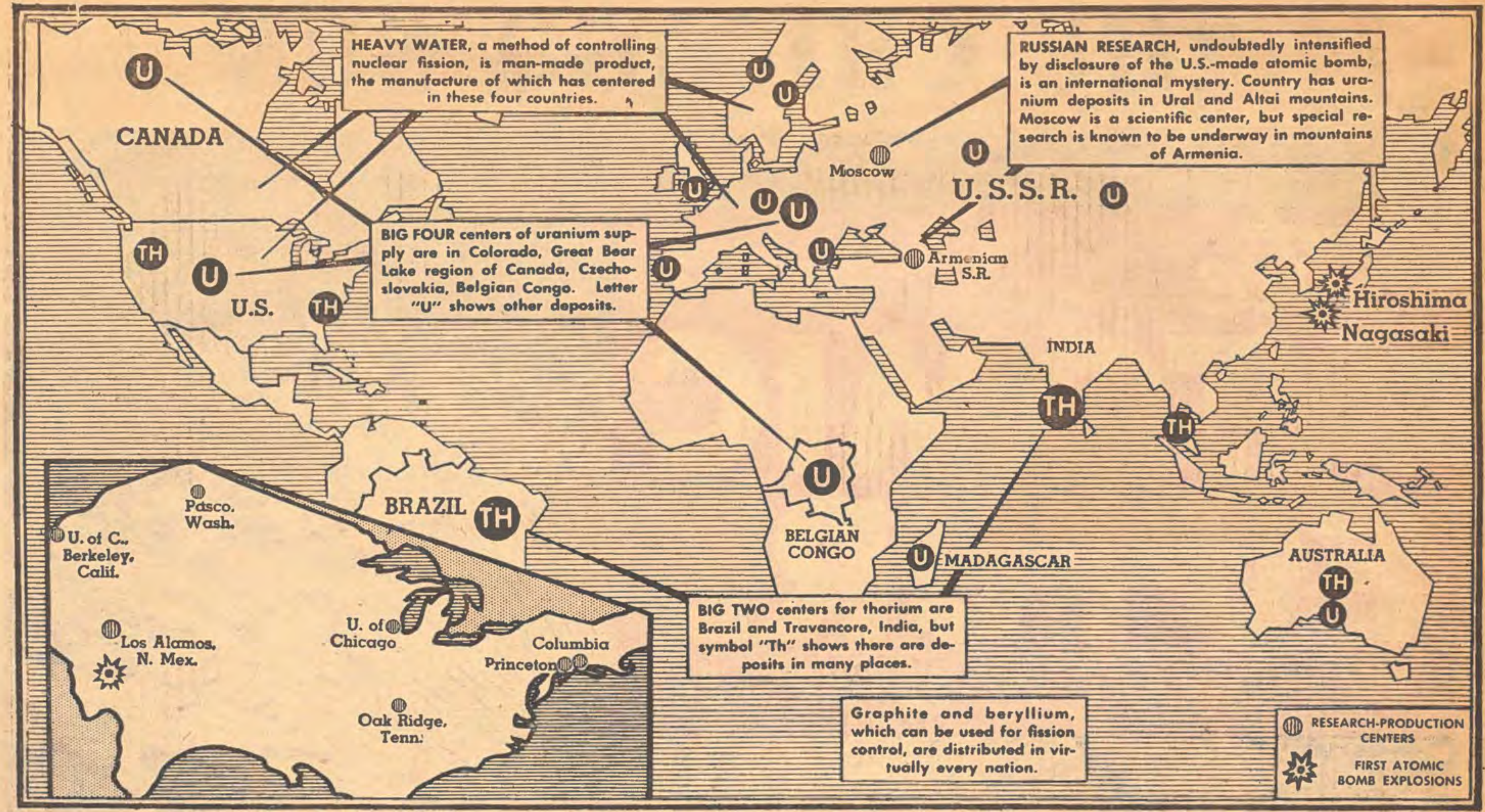
MEDICINE

RESEARCH

POWER

ENGINEERING

An Associated Press Supplement



HEAVY WATER, a method of controlling nuclear fission, is man-made product, the manufacture of which has centered in these four countries.

RUSSIAN RESEARCH, undoubtedly intensified by disclosure of the U.S.-made atomic bomb, is an international mystery. Country has uranium deposits in Ural and Altai mountains. Moscow is a scientific center, but special research is known to be underway in mountains of Armenia.

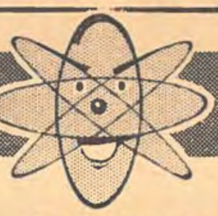
BIG FOUR centers of uranium supply are in Colorado, Great Bear Lake region of Canada, Czechoslovakia, Belgian Congo. Letter "U" shows other deposits.

BIG TWO centers for thorium are Brazil and Travancore, India, but symbol "Th" shows there are deposits in many places.

Graphite and beryllium, which can be used for fission control, are distributed in virtually every nation.

This map shows some of the areas around the world which have been brought into the spotlight by the atomic bomb.

The Atomic Language



ALCHEMY—The medieval chemistry which sought to transmute base metals into gold, to find the universal cure for disease and to prolong life indefinitely

ALPHA PARTICLE—The nucleus of a helium atom. Many elements emit these particles during radioactivity

ATOM—Smallest unit of a chemical element.

ATOMIC OVEN—A power source whose heat comes from splitting atoms.

ATOMIC WEIGHT—Weight of an atom in atomic units. This unit is, one-sixteenth of the average weight of oxygen atoms. A hydrogen atom, lightest weight of all the elements, weighs almost exactly one atomic unit.

BETA RAYS—Rays made of electrons or positrons

CLOUD CHAMBER—A sealed box with glass top filled with air or other gas rich in moisture. When the gas expands any atomic particle or atom, flying through the cloud chamber, shows its presence by a string of water droplets, resembling clouds, in the form of long thin trails. The water droplets condense on the electrified gas particles created by the passage of the atomic particle.

COSMIC RAY—An atomic particle coming from space with energies that usually drive it completely through the earth's atmosphere and deep into the ground.

CYCLOTRON—An electro-magnetic instrument that impels atoms or atomic particles around in a circular course until they have speeds corresponding to millions of volts of energy

DEUTERON—The nucleus, or core, of an atom of heavy hydrogen. This form of hydrogen has an atomic weight twice that of ordinary hydrogen.

ELECTRON—One of the three primary particles that form all atoms. Electrons have a negative electrical charge. Their weight is an 1800th that of the other two particles, namely protons and neutrons

FISSION—A division of the nucleus of an atom into two nearly equal parts.

GAMMA RAYS—The rays from radium and many other elements during radioactivity of the latter They are identical with X-rays. X-rays are produced by power tubes and in the early days never were as penetrating as the similar rays from atoms

HEAVY WATER—Water whose hydrogen atoms are deuterium, that is, heavy hydrogen of twice the weight of ordinary hydrogen.

ISOTOPE—The name for different kinds of the same chemical element, where the difference is in atomic weight. All the isotopes of any element have the same number of outer electrons as the element itself.

MESON—Also called mesotron. A particle, apparently complex in structure, intermediate in weight between an electron and the heavy particles, neutrons and protons.

NEPTUNIUM—A heavy metal created in atomic ovens by transmutation of uranium.

NEUTRON—One of the three primary particles that form all atoms. It has no electrical charge and is 1800 times heavier than an electron.

NOVAE—New stars, so called because they are explosions in existing stars that were previously either invisible or much fainter. Novae are temporary, reverting usually to about their former brightness in a few months or years.

NUCLEUS—The core of an atom. It is composed of protons and neutrons.

POSITRON—A positively charged particle of the same light weight as an electron.

PLUTONIUM—A heavy metal, produced by transmutation of uranium in atomic ovens. Plutonium atoms split to make bombs and to furnish atomic power.

PROTACTINIUM—Element 91, a heavy metal, next below uranium in atomic weight. Protactinium's atoms split with 200,000,000 electron-volt energy releases, but this element is very rare.

PROTON—One of the three primary particles that form all atoms. Protons are heavy, about 1800 times the weight of electrons, and have positive electrical charges.

RADIOACTIVITY—The emissions of rays by the nucleus of an atom.

THORIUM—Element 90, a heavy metal. Its atoms are the third heaviest among natural elements.

TRANSMUTATION—Changing one metal, or one element, into a different metal or element.

URANIUM—Element 92, a heavy metal. Its atoms are the heaviest of the naturally occurring elements. One of uranium's isotopes, U-235, splits easily. The principle isotope that forms 99 percent of uranium does not split easily enough to make bombs or power. (Plutonium, which is element 94, exists in nature but in amounts too small to be more than detectable.)

WAVE LENGTH—The distance between two wave crests.

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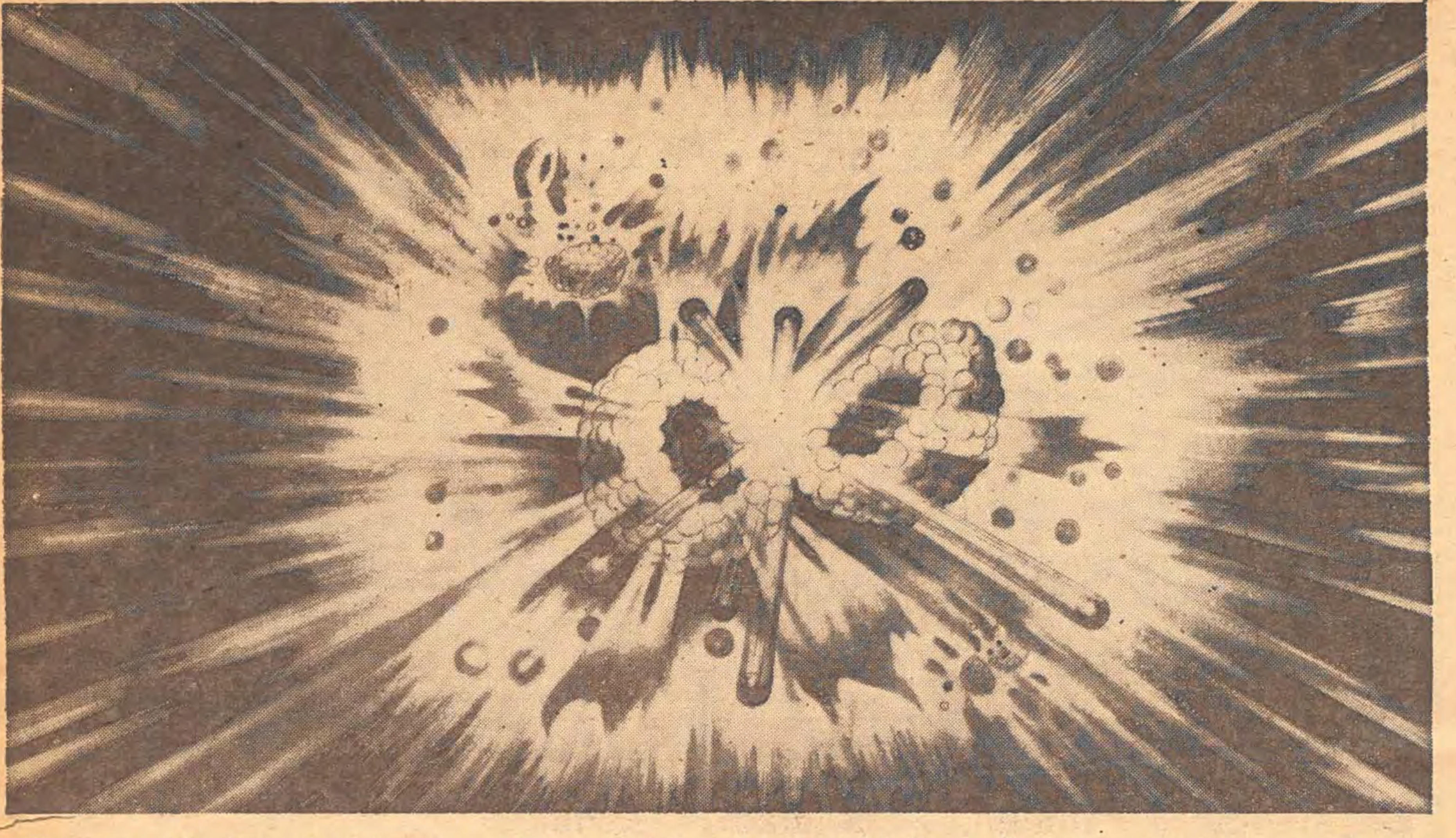
THE ATOMIC FUTURE

By HOWARD W. BLAKESLEE
Associated Press Science Reporter



"The explosion at Hiroshima on Aug. 6 slammed a door shut on the past."
—The Association of Oak Ridge Scientists

IMAGINE a slice of pineapple out of a can, magnified until the slice is nearly half a mile wide, and its color jade green because it is made of glass. That is the symbol of the atomic bomb, stamped on the face of the desert in New Mexico, where the surface of the earth boiled in the most terrific heat this world has ever known.

This symbol lies in the south central part of the state not far from that part of the old Santa Fe trail which early Spaniards called *Jornada del Muerto,* which means "journey of death." That part of the trail was so named because travelers sometimes died of thirst. Adjacent to this trail is an immense oval amphitheater, roughly fifty miles by eighty, which goes today by the military code name of Trinity. This name designates the proving ground for atomic bombs. The place is mostly bordered by mountains which are steep, sharp-peaked, in browns, deep reds, and dark yellows, with low bushes around their feet. The oval itself is a great mesa. The earth is light brown to yellowish-grey and is covered sparsely everywhere with low bushes and occasional bunch grass

At one entrance, at the foot of a spur of the Oscura range of mountains, stands a steel tower about one hundred feet high, used as a lookout by the desert patrol of the United States Army which guards all of Trinity. Out on the mesa is a small military camp, in the form of several rows of barracks, with a mess hall and a lecture hall.

Still farther out toward the center of the mesa is a massive dugout, a structure of heavy timbers faced by many feet of earth. This earth faces in the direction of a place miles away having the military code name of Zero. That is where the first atomic bomb was exploded just at early dawn on July 16, 1945. The dugout was the nearest observation point.

THE DESERT'S PROPHECY

NEVER before was there a crater like Zero. There the prologue of the future is stamped on the desert The outlines, and some details of everything to come, can be seen or sensed.

Zero emitted X-rays, or gamma rays, intensely at first and diminishing later. The solid earth was pushed down about six feet. The pressure that did this was a military secret but the British announced an astonishing figure. They said that pressure was millions of times one atmosphere. One atmosphere is fourteen-and-a-half pounds per square inch. This figure was probably a typically British understatement. The heat that boiled the face of the earth was millions of degrees Fahrenheit. That is far hotter than the surface of the sun, and higher than many estimates that used to be current about the temperature in the sun's interior.

It is quite possible that there never was any crater in the universe just like this. For atomic explosions do not appear to occur naturally on planets. They seem very rare in stars, where they do not leave craters. The two bombs on Japan were exploded at heights much greater than the bomb in New Mexico. Those heights were deliberately chosen so that the ground of the Japanese cities should not be made radioactive like Zero. The Japanese physicist, Nishina, who was in Hiroshima the day after the explosion, said the earth there was not unduly radioactive. The bomb at Zero was exploded at the top of a 100-foot-high steel tower that vaporized in the ensuing heat.

***HOWARD W. BLAKESLEE,** the author of this supplement, has been an outstanding newspaperman for more than 40 years and one of the country's leading science reporters for almost 20.*

Winner of a Pulitzer prize for science reporting in 1937 the Wilson L. Fairbanks award in 1939 and the National Headliners Club award in 1940, Blakeslee is known widely for his ability to write simply and interestingly so that readers can understand even the most difficult scientific subjects. When the atomic bomb was first announced, his stories explaining its principles were featured in newspapers throughout the world. He has visited the bomb production plants and interviewed many of the scientists who helped develop the first bomb.

Blakeslee has been an Associated Press staff member since 1905, has served as news editor in Atlanta, Chicago and New York, and as The A.P.'s science expert since 1928. He is a member and past president of the National Association of Science Writers.

The Zero crater is three concentric rings, with a total diameter of nearly one mile. The inner ring is a shallow saucer, of bare, brown earth, about 300 feet in diameter where some of the soil was blown out by the explosion. Outside that the second concentric ring is the green glass surface where the earth fused and boiled. The diameter of the glass ring is nearly half a mile. Outside the glass is a third ring that is bare desert earth, denuded of bushes and everything, just as if it had been swept clear by a gigantic broom.

The depression in the crater is about one thousand feet in diameter. This hollow is in the form of a big shallow saucer, with a smaller saucer at its center. The larger saucer is where the earth was forced down by the pressure, and comprises much of the jade glass area The smaller saucer is the blown out portion of the center. Each saucer is about six feet deep at maximum, making the total depth at the center about twelve feet

EXPLORING ZERO

ABOUT six weeks after Zero was formed, a large party of observers entered the crater and walked all over it. They were led by Major General Leslie R. Groves, the head of the atomic bomb project. All of them put heavy canvas packs over their shoes. The canvas was to insure against any small particles of sand sticking unnoticed to shoes. Most of the sand was as safe as ordinary dirt, but here and there a minute particle might be emitting X-rays, gamma rays or other rays such as high speed electrons or heavier particles Gamma rays are highly penetrating X-rays.

In the three-hundred-foot dirt saucer at the center of the crater the concrete feet of the vaporized tower were standing apparently undamaged. They were about waist high. They were round, narrow piers, and out of the top of each projected some stubs of steel which originally were part of the base of the tower. Above all three piers these pieces of steel had been cut off at the same level as if the job had been done by one sweep of a giant knife. But the cuts were not those of a knife. The metal had been pulled apart like soft molasses candy.

The glass ring outside the central crater was made of desert earth, largely sand, that had fused in the terrific heat to depths of a quarter to half an inch. Only the top surface of this fused area was glass. The glass ranged from the thickness of an eggshell down to very thin paper. Underneath, the fused

BLAST, HEAT AND RAYS MAKE ATOMIC BOMB A SUPER-KILLER

earth was merely hard and as black as if it had been soaked in petroleum.

Everywhere the glass was covered with bubbles—millions of them, frozen into every conceivable size from little more than a pinhead up to an occasional half-inch in diameter. They were so fragile that many broke at a touch. Most were jade green, but here and there the color shaded off into turquoise. There were some red bubbles, and occasionally a strong blue due to a difference in the chemical composition of the soil at those points.

Small stones lying in the central saucer of the crater had evidently boiled on one side, leaving a very thin hard crust which did not scratch off. Here and there was a stone whose surface on all sides had been converted into powdery blue. A few stones apparently had cracked in the heat. In the fused earth there were occasional odd formations such as the shape of a perfect egg. One of these when picked up had a shell of green glass completely covering it. The lump was so fragile that it broke under the pressure of two fingers, revealing an interior of desert sand, most of it apparently entirely unaffected by the heat.

Near the center of the crater lay a brick with all but its face buried in the earth. When this brick was dug out it could be broken by two hands into dozens of small pieces. It had been baked by the flash so thoroughly that not only did all of its original chemical components group themselves into little pieces that could be split apart, but each piece was likely to be of a different shade of color from the one adjoining.

The inner ring of the glass surface was about as uniform as the inner ring of a slice of pineapple The outer edge was entirely different in shape. This edge was jagged, saw-toothed, and with long spikes thrust outward sometimes a hundred feet or more This entire glass surface was shaped almost exactly like the familiar drawing of an explosion by a comics artist. In fact, the glass surface was a real explosion frozen on the face of the desert.

The bare zone outside the glass marked the limit of the area of total destruction on the surface of the ground. In the air this diameter of nearly a mile was not the limit of virtually total destruction. In all explosions the earth's surface is likely to be the safest place at any given distance, as was learned by millions who "hit the dirt" in the war that produced this atomic bomb.

Inside the three rings of total destruction on the earth's surface numerous instruments had been set up on the ground to give readings of the explosion All were destroyed. That particular destruction was very satisfactory in this case, because the instruments were set there to tell what happened if the bomb fizzled. Before the explosion a line of telegraph poles only shoulder high and very heavy carrying several dozen wires, had run from the base camp miles back into Zero. Within the mile-wide crater, poles utterly disappeared and most of the wire vaporized. Here and there was a fragment of wire, and in the crater a few unexplained chunks of iron were still emitting enough X-rays weeks afterwards to take photographs through solid objects. For a long distance outside the zone of total destruction the poles were destroyed or down. Mostly there was nothing above ground to be destroyed in this mesa except low bushes. Some of these outside the zone of total destruction appeared to be leaning away from the center of the explosion

Just outside the outer zone of bare earth sat a huge iron vessel shaped somewhat like a milk bottle. This bottle was sitting erect without a visible tilt, an evidence that sufficient mass is some protection against the force of even an atomic bomb. Over the vessel there had been a tower. Its remains were lying out on the desert beyond completely blackened and spread almost flat.

The iron bottle was set up for an unexplained experiment. It was made of steel about six inches thick. Although the blast did not blow it over, there were radio-active rays which might have penetrated into steel even at that distance. The iron vessel was suggestive of the sort of protection that heavy armor on war ships may afford. These suggestions apply only to bombs exploded in the air and in no way to atomic bombs detonating under water.

About three weeks after the explosion, the desert in that vicinity bore the smell of dead snakes, ground squirrels, and other small animals. The morning after the explosion, a bat was found many miles away hanging to a rafter, apparently unhurt. The animal's eyes were open and it made no attempt to get away from men who examined it and touched it. It was oblivious to everything that went on.

Zero's face bears the records of three great forces, all of them useful for the future. One is heat. An observer of the explosion, many miles away, his back to Zero, and facing a mountain range that was not very close, felt on his face the reflected heat from the mountains at the instant of the explosion. In a camera, six miles from the explosion, the first two frames of the film were partly burned. On the sensitive emulsion small spots were destroyed by the heat. After the first two frames, there was no further spotting, a fact that shows how rapidly the heat dissipated.

Temperatures of this sort were never before available. Although their maximum is far too great for useful ends, the energy that produces them can be spread out over longer periods of time, and so can be harnessed for work. The pressures likewise can be reduced to smaller packages, within the range of use in existing machines, and in machines of the future that will be made of stronger alloys than any now existing. The nuclear rays are far more numerous and powerful than any radiations man has possessed. The services they can perform are surprisingly broad

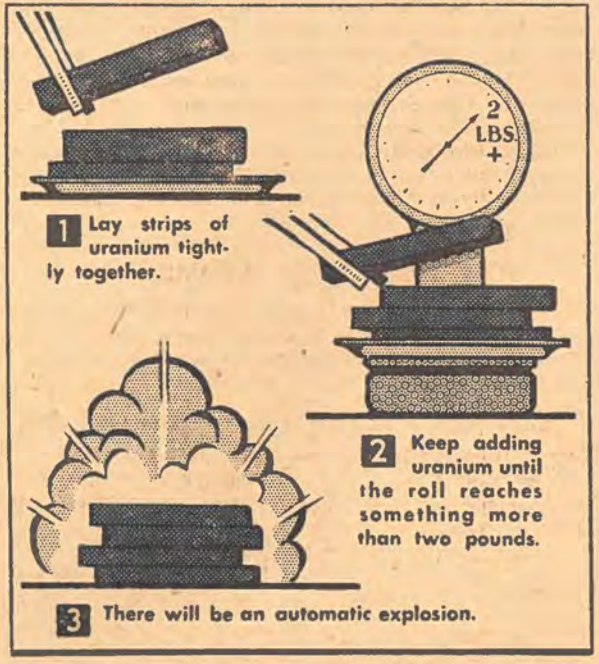
'HANDLE WITH CARE'

THERE is no such thing as a small atomic bomb The smallest is tremendous in power. No laboratory explosions could be used in advance to measure what will happen. In New Mexico, science, industry and the Army made a plunge into unknown violence and the morning of the first explosion they took no chances.

More than one hundred miles away men were around hotels inside and outside, carrying unobtrusive meters, some of them about the size of a fountain pen. It was certain that there would be no dangerous rays, in fact no rays at all, at that distance. Nevertheless the meters were read There were no rays.

The town nearest to Zero was Carrizozo, between thirty and forty miles distant The night before the explosion, about 300 military trucks, with complements of military police, parked in an inconspicuous area nearby. Orders were that if during the night the wind should blow from the direction of Zero every person in Carrizozo was to be removed to a safer distance. The Army was not looking for any danger of rays shooting directly and all the way from Zero into Carrizozo. But it was a certainty that a huge cloud of radio-active particles of the air itself, and of the dust and other impurities of the atmosphere, would be shot high into the heavens. An unfavorable wind might bring some of this over Carrizozo. The wind did not blow that direction and the people were undisturbed.

Rolling an Atomic Bomb



1 Lay strips of uranium tightly together.

2 Keep adding uranium until the roll reaches something more than two pounds.

3 There will be an automatic explosion.

A small amount of X-rays or gamma rays is harmless to man, animals and plants. In fact everyone lives in them continuously. The radium in the earth, as it decays, turns at one stage into a gas called radon. A little of this gas is always in the air, everywhere, emitting rays. There are also other sources of X-rays from cosmic rays and a few other radiations, present in the air. The fact that a radiation meter shows X-rays is meaningless, even in an area near an atomic bomb explosion, unless the intensity of the rays increases considerably.

That morning a few men were knocked down by the air blast from the explosion at varying distances. The greatest distance was twenty miles. These blasts were not different from a big wind, and the men were not hurt. Some of the scientists smeared suntan cream on their faces and hands. even when they were as far as twenty miles away. A flash as bright and hot as an atomic bomb creates some ultra-violet rays which might cause an almost instantaneous sunburn, although the burn itself would not show up until some time after the exposure. In laboratories ultra-violet rays have been created powerful enough to produce a sunburn with only one or two seconds of exposure

There had been much discussion among scientists about the possibility of an atomic bomb causing the air or the earth to explode. Those discussions mostly had taken place five years previously, and all theory and experiments had shown the impossibility of such catastrophes. But in the tension that morning the observers thought of everything.

One young man about twenty miles away was lying on his stomach. His heels pointed toward Zero. He was looking toward the Oscura mountains. It had been raining a short time before and the air was still slightly misty When the explosion came the light was brighter than anything ever before witnessed by human eyes. The intensity of light rises with the temperature of the source, which in this case was the atomic bomb flash. Although there are temperatures of millions of degrees inside the sun and in stars, human eyes never see that light because the visible rays come from the outer surfaces of sun and stars which are cooler than man's new atomic bomb. As the flash occurred, it seemed to this man that the Oscura mountains were on fire, and the intervening mists appeared as bright as flame. That observer said softly to himself:

"Oh! Oh! This is it"

The flash expanded into an immense ball at first almost as round as the sun, and then mushroom-shaped. After the dazzling whiteness faded there was a display of color. Observers of all of the atomic bomb explosions have differed in their color descriptions. They agree about the white color of the mushroom fading in intensity to cream. Most of them agree also on an amber color below the mushroom. One of the New Mexico watchers said that at the base of the mushroom stalk he saw an impenetrable column of dust descending back to earth. Brigadier General Thomas F Farrell, assistant to General Groves. said that the colors lighting the peaks and crevasses of the mountains and the whole country were searing and golden purple. violet, grey. and blue

EFFECT OF THE RAYS

WITHIN two months after the explosion at Zero there were numerous reports that the backs of some cattle in that area had become streaked with grey. This was a smoky color the length of the back and in a strip about a foot wide at the most. Thirty-five or forty calves were seen by State Inspector Alfred Hunter on a ranch about thirty miles north-east of the bomb test site. All were frosty-backed. At another site about sixty miles away a few cattle had frosty backs. In one case a bull and several cows were reported to have developed sores that looked like sunburn on their backs.

These frosty backs probably were due to particles made radio-active by the explosion that afterward may settle down rather sparsely from altitudes of ten to twenty miles. There is an explanation of what may have caused this greying in some spectacular laboratory experiments made a good many years before this first atomic bomb. In those experiments, cathode rays of high intensity directed against the fur of animals caused it to turn grey at the spot which was struck. If the rays were continued long enough, the hair at that spot afterwards fell out and a sore developed. Cathode rays are streams of electrons. They are stopped very quickly by air. Some of the particles that are transformed by the rays in an atomic bomb explosion afterwards emit electrons. They may also emit X-rays but not necessarily. If particles emitting these electron rays should settle on the backs of animals in sufficient quantity, they would be expected to duplicate the grey hair and possibly sores produced in the laboratory.

It would be very unlikely that human beings would incur any similar damage. For even a very thin layer of clothing would afford sufficient protection against these short-range rays. The most striking fact about the rays of all sorts created by an atomic bomb explosion is their temporary nature. Some of the particles of air or earth give off rays for only a few minutes. Then they stop and are just as harmless as before. Others emit rays for a few hours. Still others continue for days, and some go on radiating for months, and a few for years. But the intensity or the power of these rays is far greater from those particles which emit for only short periods. The longer a particle gives off rays, the less dangerous they are because they are weaker.

These rays work like getting wet with three glasses full of water, of equal size. The first glass is poured rapidly on your clothing until it is emptied in five minutes. The second is emptied a drop at a time over a period of a month. The third is emptied in tiny droplets almost too small to see, taking a year. The first would soak clothing much more than the other two, although the amount of water is the same. The harmful power of the rays is analogous to this kind of wetting. The long-lasting radiations are also very weak.

The morning after the explosion at Zero observers entered the crater in lead-lined Sherman tanks. The X-rays from the ground were so intense then that it would have been dangerous without this shielding. Six weeks later when General Groves led his party in, the X-rays were still being emitted, and there were enough of them so that had a human being remained in the crater continuously day and night for one month, and had kept moving around so that he would not miss any of the hot spots, the exposure would probably have killed him. But a few minutes or even a few hours in the crater at that time carried no serious risk.

The general's party remained about fifteen minutes without damage. Camera men ranged all through the crater with little or no fogging of their films. Photographic film is far more sensitive to X-ray damage than a human being is. Rays that come from particles in the air after an atomic bomb explosion are scattered so far and wide that there is ordinarily no risk. Should an atomic bomb war be fought with many bombs, then here and there the air itself might be dangerous. However, that danger would be temporary and would be mostly over in the matter of a few hours.

If bombs are exploded on the surface of the earth or in the earth the way the V-2's detonated, greater radio activity and more X-rays from the earth itself would be expected afterwards. The bigger the bombs, the more there would be of this kind of earth X-ray. But these rays also would follow the natural law of the very rapid diminishing in intensity. The earth in the crater and its very immediate vicinity might be lethal to human beings for a short time, and then dangerous for more than brief occupancy for a period of months.

THE ATOM'S 'SHADOW'

THIS New Mexico explosion brought something new in earthquake waves. These waves were made by the earth being pushed down instead of from a movement inside the earth. If atomic bombs are used in contact with the earth, or detonated at some depth, there will be serious damage from small earthquake waves. How far away these will be serious will depend on many factors, including the strength of the blasts and the character of the soil.

All explosions contain freak areas which for want of a better explanation are called "shadows." When General Groves was a young man, he and several others were close to an explosion of about two pounds of TNT. Most of the men were uninjured. Groves was badly hurt. The atomic bombs have the same shadows, but with an additional risk.

At Hiroshima ten Japanese soldiers were sitting on a bench on the parade grounds of the military headquarters. They were not far from the central part of the blast. They should have been killed almost instantly by the blast itself or by the terrific heat as were many other persons in their vicinity. But all of them were apparently uninjured. A day or two later one of them died, and within a few more days, others died. All these deaths were due to X-ray burns or burns caused by rays of neutrons. The symptoms of both burns are similar.

One after another these soldiers died until only one was left. Nothing happened to him. Whatever may have hit the other nine, this one escaped. That incident suggests that there may be the so-called shadows in the X-rays and neutron rays of an atomic bomb flash.

But those who escape the crushing blast and the heat familiar in ordinary explosions are subject to the added risk of flash atomic rays. The flash rays are not the same radiations that may linger in the crater, or in the air after the explosion, although they are the same kind. The flash rays last only a fraction of a second, and disappear as instantaneously as the blast of fire that they accompany. These quick rays do not apparently extend much farther from the center of an atomic explosion than do the fire and blast effects. But within these limitations, they are a new and vicious form of death by explosion.

It was an engineering and scientific miracle that the first atomic explosion was free from accidents. But it was a carefully calculated miracle, and as such is repeatable. However immense this nuclear energy may be, it is not beyond the control of man. It may be a monster, but it is not a Frankenstein monster.

ROLL YOUR OWN ATOMIC BOMB

MAKING an atomic bomb is in principle simpler than rolling a cigarette. The cigarette bomb would not be very effective, probably only a big fizz, likely fatal to you, but it illustrates the startling nature of an atomic bomb.

To roll this bomb, substitute for tobacco uranium of the atomic weight 235, or plutonium, the new synthetic metal. These metals are hard, like iron. Uranium's natural color is silvery. But because of tarnish it resembles the colors of very dark brown tobacco. It is nearly twice as heavy as lead.

The cigarette would have to be rolled with small strips of this heavy metal. When the roll reaches a weight that is a military secret, but that is something over two pounds, this cigarette will light and explode. No match is needed, nor any other lighter. There is no trigger mechanism required. In fact, nothing can stop the explosion. It is only necessary to bring together enough of the pieces of metal.

The situation is the same as if your tobacco cigarette would light itself. For an effective bomb, the weight of metal that must be brought together is much more than two pounds.

A cigarette burns because of the oxygen in the air. Shut off this oxygen, and the burning cigarette would be extinguished instantly. The atomic bomb does not use oxygen, but explodes on account of something else that, like oxygen, is present in the air.

The substitute for oxygen is neutrons. These are one of the three particles out of which all atoms of all kinds of chemical elements are formed. The others in the trio are protons and electrons. Look at your hand. Nearly half its weight is made of neutrons. More than half the weight of the uranium is made of neutrons. Everything in the universe, hydrogen alone excepted, consists of half or more of neutrons. Ordinarily these neutrons are so tightly bound in the cores of atoms that they never get out.

But the air always contains some free-flying neutrons. It is possible to listen to them, with an electrical instrument that clicks every time an electrified, that is to say ionized, atomic particle strikes the instrument's sounding board. The clicks average 30 to 100 a minute, and some are indirectly due to neutrons. The source of these free neutrons is cosmic rays, the mysterious, high-speed particles from space that drive completely through the earth's blanket of air and deep into the ground. The rays jar neutrons loose from atoms in the air. The neutrons are not as numerous as particles of oxygen. But they make up for that by getting around. Their initial speeds are about 9,000 miles a second.

Neutrons penetrate steel, lead and other heavy elements like a rifle bullet going through cheese. They pierce the metallic covering of an atomic bomb. When one of them hits an atom of uranium 235, that atom usually breaks in two. From the split several neutrons emerge. These hit other uranium atoms. In this way a chain reaction starts in the metal, like the chain reaction of a burning cigarette or that in the explosion of T.N.T.

There are enough free neutrons in the air to set off the atomic cigarette bomb, or a real bomb, instantly. There is also an additional guaranty of immediate explosion of the metal. The explosive atoms also split spontaneously from time to time. This happens often enough to light either the metallic cigarette, or an atomic bomb.

If for any reason the scientists do not wish to rely on the spontaneous explosion of an atomic bomb, a neutron trigger can easily be placed in the bomb. A very small amount of radium mixed with beryllium emits a constant stream of neutrons, and such a stream would be a good trigger.

URANIUM'S REALLY SAFE

IF URANIUM and plutonium explode so easily, why does not the uranium in the earth blow up, and why must there be more than two pounds of the metal gathered together before it will explode? Your cigarette will answer both questions. Unroll the cigarette and scatter the tobacco on a table. It is possible to burn this cigarette tobacco, but that will have to be done piece by piece. The burning will require many matches, and if the tobacco particles are well scattered, no burning particles will set fire to any other grain of tobacco. That is to say there will be no chain reaction, and chain reaction is what happens in a burning cigarette.

The atoms of the explosive uranium 235 are scattered in minerals of the earth like a handful of tobacco thrown over a table. Really these atoms are scattered far more effectively. If a handful of cigarette tobacco were tossed into the air during a hurricane, the amber grains might not be separated by the wind as effectively as nature has scattered the explosive uranium. This scattering is, atom by atom, distributed throughout normal uranium, which has an atomic weight of 238, and which does not explode. In this normal uranium, only seven-tenths of one percent is composed of atoms of the 235 variety.

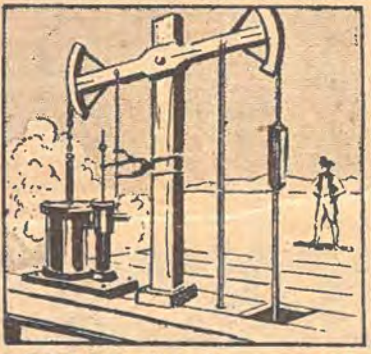
Why must there be more than two pounds of uranium 235 before an explosion is possible? The cigarette gives the answer. Take a very small pinch of tobacco. Roll it in the paper. You can light it, but the tobacco will not continue to burn, because

Harnessing the Atom Ranks with Greatest Discoveries of Man

FIRE—Its initial use by man is shrouded in antiquity, but it is believed to have marked an important milestone in the change of status from mere animal to human.

AGRICULTURE—With the development of crops and the domestication of animals, man for the first time was able to set up cities and organized nations.

THE WHEEL—Prehistoric civilizations got along without it, but the wheel has been basic in the development of modern cultures. Without it industries are impossible.



POWER—Development of steam and internal combustion engines gave man time for cultural progress and made possible the industrial revolution.

ATOMIC ENERGY—This could step up man's potentialities to unguessed heights. It may revolutionize his way of living and permit him to explore earth's outer space.

there is not enough tobacco to maintain a chain reaction, that is, the ordinary fire.

Uranium requires more than two pounds for a somewhat similar reason. The large minimum weight appears surprisingly great to people not acquainted with atomic fire. In an ordinary fire, as in a cigarette, the heat spreads from one grain to the closest adjacent grain. Neutrons do not spread their atomic fire, that is their atom-splitting effects, by moving from one atom to the next closest atom. Instead, the neutrons travel quite a distance as a rule before they hit an atom. In some cases this average distance is about one inch before hitting and splitting a uranium atom.

But of the two, the cigarette which contains only a pinch of tobacco, or the atomic cigarette which contains too little metal, the atomic cigarette is much the safer. The abortive ordinary cigarette might start a fire. The atomic bomb that is too small is as safe as dirt. Nothing explodes it. Like dirt, this atomic bomb metal can be melted in a furnace, but even in a furnace the atomic bomb metal would not explode.

This cigarette bomb would be inefficient, actually only a big fizz, for a remarkable reason. The neutron explosion in uranium moves so fast that there are only a few millionths of a second between the start and the completion of the reaction. A very large part of the power of this explosion appears to be confined to the extraordinarily brief interval of one ten-millionth of a second. Human hands, going through the motions of rolling a cigarette. cannot move so fast.

As the cigarette bomb pieces are brought very close to each other, the atomic fire would start, and would spread so fast that much of the metal would be blown away before the explosion reached terrific proportions. In order to explode, the uranium metal must be packed together. Any pieces which do not explode during this packing become non-explosive as soon as they separate from the main mass.

How it is possible to assemble a few pounds of uranium, or many pounds, so rapidly that even a fair fraction of the metal has time to explode is one of the secrets of the atomic bomb. Perhaps this is the main secret, because most of the other secrets were about the application of techniques of manufacturing metal that men had done before. Not even the dreams of magic ever conceived anything as swift as the assembly of this atomic metal. The pieces of metal are set up at or near the center of the bomb, separated by distances, and other factors which make them safe from explosion. The real trigger of an atomic bomb is the mechanism which starts and completes the assembly of the explosive metal.

WELL-KNOWN PRINCIPLES

ALTHOUGH the assembly technique is a secret, the principles that were employed are not. They were released to the world in the official Smyth report six days after the first Japanese bomb was dropped. The report gives four principles. One is the use of a gun to shoot the pieces of uranium together. This gun is a small piece of artillery. The only facts revealed are that the principles of this piece are not very greatly different from those of more familiar types of guns. Inside the bomb, part of the explosive metal is fixed as a target. The other sections of metal are shot against this target. But even projectiles shot from a gun do not move fast enough for the assembly of an atomic bomb. For example, the bullet or shell from a gun of high velocity moves much less than an inch in one millionth of a second.

A second principle is the shape of the pieces of metal. To understand this, double both fists. The shape of a doubled fist is roughly that of a half sphere, like a baseball cut in two. Assume that each fist is made of uranium metal but not enough to explode. Bring the two fists together, knuckles touching, and they would instantly explode. Now repeat, but instead of doubled fists, open your hands with fingers stretched straight. In this shape your hands still represent the same weight. Now bring the palms together and, if they were uranium metal, they would never explode. They would be quite safe.

This analogy is over-simplified. Actually it would be probably necessary to iron out these two rounded pieces of uranium into thin flat plates. However, the fists and the palms illustrate the principle. In the flat shape, because neutrons have to travel so far before they hit an atom, only the neutrons traveling lengthwise in the plates could do much splitting. The neutrons flying in all other directions would nearly all escape without exploding an atom. This escape of neutrons is the explanation of the use of shape in pieces of metal in the bomb assembly.

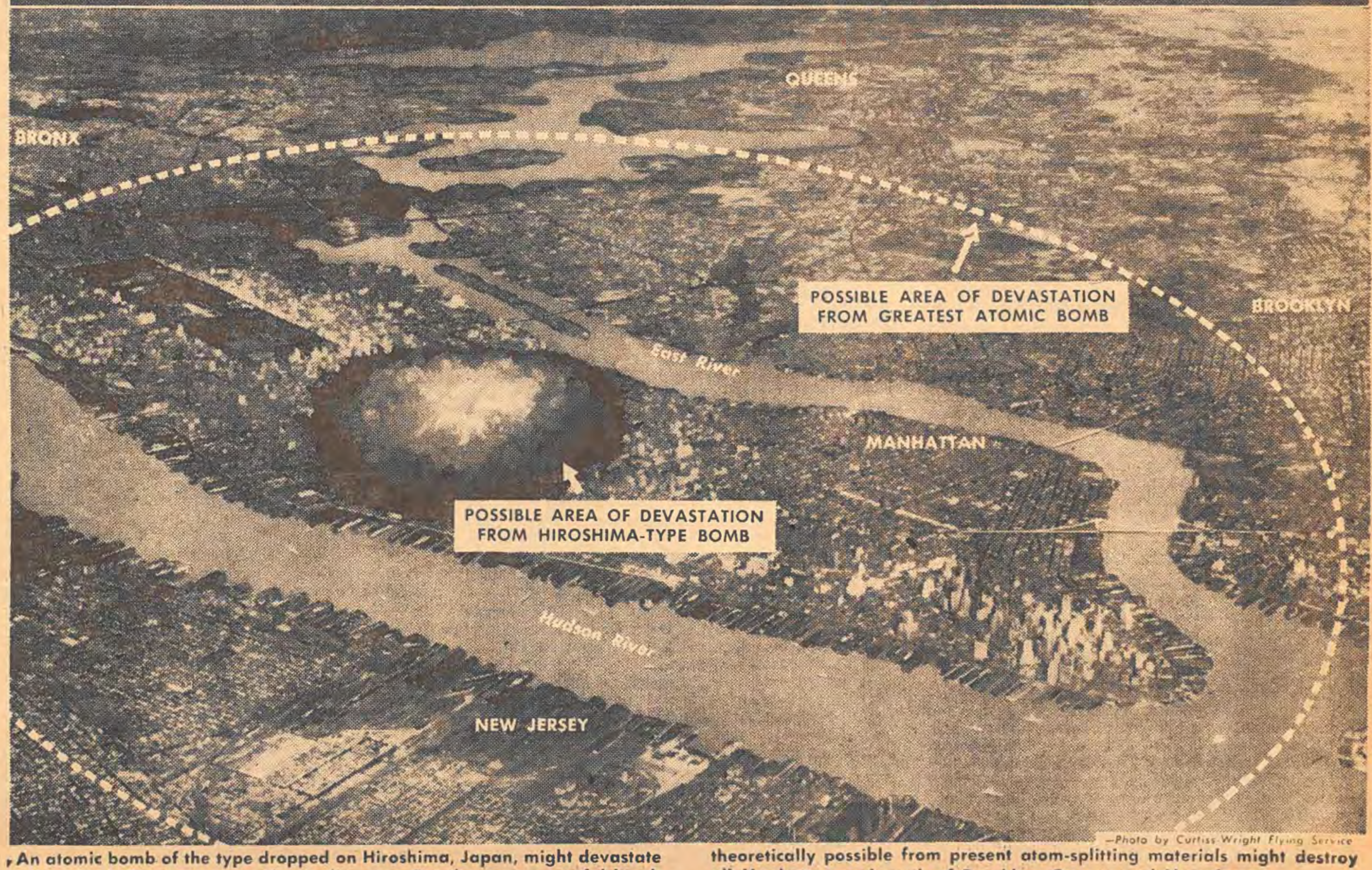
A third principle is the use of chemical elements which absorb neutrons. The white metal cadmium is one of these absorbers. Boron is another absorber.

When a neutron is absorbed in cadmium or boron it is completely finished. It does not move any further. It does not split the atom which absorbs it. It is no longer able to take part in the atomic explosion. Absorbers of these or other types are placed in the bomb assembly in such a way that they slow down the explosive chain reaction at its start. As the reaction approaches the climax, these absorbers are somehow neutralized or withdrawn. How that can be done so quickly is another feat that outdoes all the dreams of magic.

The fourth principle is to surround the assembly of explosive metal with a peculiar kind of mirror. This is a mirror which does not reflect light, but does reflect neutrons. In spite of everything that can be done, some of the neutrons escape from the metallic assembly without splitting any atoms. The mirror reflects these neutrons back into the uranium or the plutonium. This bomb mirror is made of a dense metal. There are a number of heavy metals which would make good neutron reflectors. The one chosen is a secret, but examples of what they might be, so far as density is concerned, are lead, platinum, gold, or osmium. The latter is the heaviest of all the naturally occurring metals.

The secrets of the atomic bomb are much like those of a sixteen-inch gun. All nations know how to make one of these weapons. But the formula used to produce the gun metal is a secret of each nation. So, too, is the precise pitch of the rifling in the gun barrel, and likewise other details. In the atomic bomb one of the secrets is the amount of metal used. There have been a number of published estimates of this weight of metal, apparently all of them guesses. For example, when President Truman announced the explosive power of the bomb dropped on Hiroshima as about 20,000 times that of TNT, many people were able to figure immediately how much metal was in that bomb. provided all of it

One Bomb Vs. New York—Now and in the Possible Future


QUEENS
BRONX
POSSIBLE AREA OF DEVASTATION FROM GREATEST ATOMIC BOMB
BROOKLYN
East River
MANHATTAN
POSSIBLE AREA OF DEVASTATION FROM HIROSHIMA-TYPE BOMB
Hudson River
NEW JERSEY

—Photo by Curtiss-Wright Flying Service

An atomic bomb of the type dropped on Hiroshima, Japan, might devastate a New York City area two miles in diameter. But the most powerful bomb theoretically possible from present atom-splitting materials might destroy all Manhattan and much of Brooklyn, Queens and New Jersey.

exploded. The amount would have been between ten and fifteen pounds. However, it is impossible to believe that the very first bombs attained 100 percent efficiency. In fact, such rapid progress was made that when the third bomb was dropped on Nagasaki a few days later, it was, by official announcement, more powerful than the Hiroshima bomb.

There are other reasons than just how much metal can be exploded involved in producing more powerful bombs. However, the evident fact remains that the first atomic bombs were nothing like cigarette size or baseball size.

IF THE BOMB GOES THE LIMIT

THERE is no escape from the terrible destructiveness of atomic bombs. There is a theoretical limit—the most powerful atomic bomb that can be made with the present atom-splitting metals.

This limit is a single bomb that should completely destroy Manhattan, along with much of Brooklyn and Queens across the East River and some of the Jersey cities across the Hudson.

There is no early prospect that atomic bombs of this extreme power ever will be attained. In fact, nothing like that power should be necessary even though atomic bombs were used to devastate all the civilized nations. One of the most difficult facts to realize is that atomic bombs do not stop where other bombs leave off. The atomic weapons belong to a completely different range. Only one-tenth of one percent of the intrinsic energy in the explosive atoms is released by the splitting. Nevertheless, if only one percent of this sort of splitting is obtained, the resulting bomb is far more powerful than anything made by ordinary chemical explosives.

Fantastic stories that atomic bombs will destroy everything within forty to eighty miles radius are based on complete misconceptions of the laws of nature. When the explosive power of a bomb, atomic or otherwise, is doubled, the distance of destruction is not doubled. For example, if a certain bomb would destroy everything within a radius of one mile, a bomb one thousand times more powerful will have a destructive radius of only ten miles. The terrible fact is that at the very beginning of making atomic bombs, while they are still crude, it is not necessary for an aggressor nation to possess either the best bombs or the most bombs in order to destroy its enemy and a large part of the enemy population.

Uranium has been considered one of the comparatively rare minerals in the earth's crust. The prewar estimates will be revised for a number of reasons known to geologists, chemists, and mining engineers. But assuming that only the limited prewar amounts should ever be available, there is still enough of this fissionable material to destroy all the cities in the world.

The first atomic bombs were very expensive. But soon after the war ended, the bomb experts themselves said it would be possible before very long to make atomic bombs at about one-thousandth the cost of the first ones. There was no question but that atomic bombs could become both cheap and plentiful. There was no question that there would be improvements in all the techniques required to produce the material and make the bombs.

One of the destructive powers of atomic bombs at first little mentioned by the experts, particularly some who tried to belittle this weapon, is the incendiary effect. In World War II incendiary bombs did far more damage than high explosive. The atomic bomb is by far the most incendiary weapon ever invented. The heat of millions of degrees starts fires instantly. Fireproof walls are little protection. Concrete structures may stand without much apparent damage, and a few actually did so in Japan. But the blast broke windows and the flash of heat boiled and eddied throughout the buildings, starting fires wherever there was anything inflammable. A temperature which vaporizes steel and likewise vaporizes human beings close to the center of an atomic bomb flash is probably the most dangerous starter of fires that exists outside of the sun and the stars.

An example of fire damage was a military hospital at Nagasaki. This structure was concrete and stood on a hill bordering the atomic explosion area. Glenn Babb, Associated Press foreign editor, inspected this building after the explosion. He found the place more or less intact. The windows and doors were gone. But the walls looked good, floors seemed undisturbed and stairways were all in place and apparently undamaged. The hospital appeared as if it could be put to use again simply by renewing doors and windows, and moving in new furniture.

Mr. Babb was informed that there had been about 600 personnel in the building at the time of the explosion, and that all were dead. One room on an upper floor had been used for storage of papers. These papers had been piled flat, in tight bundles, an arrangement that makes paper difficult to burn. The piles of paper had reached half way to the ceiling. After the explosion nothing was left in that room except a foot-deep layer of very fine powder.

DEATH OVER THE POLE?

THE atomic power now being developed makes it virtually certain that V-2 types of weapons will drive atomic bombs, if they are used in the future. It is anybody's guess on how long it will require to make projectiles of this sort with ranges of thousands of miles and accurate enough to hit a city of 100,000. That much accuracy is well within the theoretical possibilities.

Almost as dangerous is a different method of attack that was perfected thousands of years ago and has been used ever since in varying forms, with its most famous example the Trojan Horse. Enemy agents might be difficult to detect coming from a supposedly friendly nation, and each one carrying a small amount of uranium. Due to its weight, the size of the pieces would be inconspicuous.

Furthermore, the rays this explosive metal emits are not easy to detect. These rays are weak and are mostly heavy atomic things known as Alpha particles which do not travel far and are not detectable like the rays of radium. The presumed secret agents could assemble the necessary pieces of metal in a time bomb mechanism. Such a bomb big enough to destroy a large area would not be too conspicuous. Places like basements could be found in which to set it off.

With expected improvement in radio, bombs of that sort might be exploded simultaneously by pressing a key at some remote control point. There are also the possibilities of producing fairly destructive tidal waves against coast cities and of exploding atom bomb ships in harbors.

Atomic bombs will change some of the tactics of war. A few of these changes already are in sight. One will be what nations may call "Operation Polaris," meaning bombardment by atomic shells fired over the North Pole.

This Pole is on or near the shortest air route between some of the nations that in the past few centuries have initiated or waged the world's great wars. Looking down from on top of a mythical North Pole, an observer could see them all. There would be the European nations, particularly those northern countries that have been strong in war since the fall of the Roman Empire. There would be all of Russia and her Siberian possessions. Also bordering or within reach of this Polar Sea would be Japan, the United States and Canada.

To some of the military targets in these countries, the best route would be over the Polar Sea, sometimes over the Pole itself. Warplanes may some day fly those short routes. The Russians flew over part of the Polar Sea in one of their demonstration flights to America, before the war.

Atomic rocket bombs, of the future V-2 type, may find other advantages, in addition to shortened distance, over the Polar Sea routes. There may be less radar observation to detect them than when they cross other oceans. The Polar Sea, it is likely, will have fewer ships or bases capable of sniping at high-flying atomic rocket bombs with proximity-fuse weapons.

The point has been made that atomic bombs may not be particularly effective against armies deployed in field operations. Even the wide spread of destruction—a radius of miles in future atom bombs—might not put out of action a significantly large number of enemy troops. It must be remembered, however, that rocket bombs probably will be one of the cheaper forms of attack. Their devastation per square mile will cost less than that attained by saturation bombing with ordinary bombs.

There is a more important point in their use against troops in the field. This is based on the thing in atomic energy that is different from all other forms of bomb damage. That thing is the radioactive rays. These rays can be used against troops in the field in two ways. One is to explode the atomic bombs near enough to earth to render large areas temporarily radioactive. These areas would become untenable. For a time after the bombing they would be dangerous to life even for short stays.

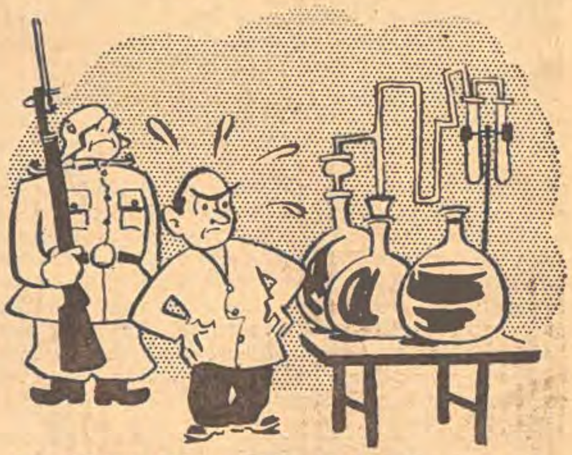
Such an unheard of thing as a radioactive ray barrage has to be considered if atomic wars are fought.

The second tactical use of the rays will be in the air itself, which is made radioactive, and in the dust and other impurities of the air that also emit dangerous rays after an atomic bomb explosion. Normally these particles are driven to altitudes of many miles, where they disperse with little risk to human beings. But winds affect this distribution. Heavy, rainy weather is likely to cause large quantities of the particles to be precipitated back to earth while they still are dangerous. Favorable weather conditions could be used to insure a dispersal of the ray-emitting particles over a large

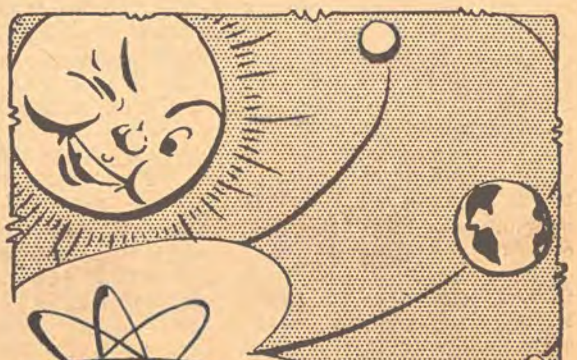
Atomic Oddities

THE NAZIS drove out some of the scientists who might have produced bombs for them.

THE TEST BLAST in the New Mexico desert was felt 160 miles away.



DR. ENRICO FERMI, while working for the Axis, almost discovered how to split an atom. Only a strip of aluminum foil in his apparatus prevented success. He later served the Allies.



THE ATOM'S STRUCTURE is in many important ways like that of the solar system.

ALL MATTER IN THE UNIVERSE IS MADE UP OF ATOMS

territory, far in excess of the limits of damage from the direct atomic explosion.

ONE IN TEN MIGHT DIE

THE future defenses against atomic bombs are unlikely to be anything that will explode the bomb in the air before it reaches its destination. There will be many kinds of defense of the same kind that armies and navies always have used, if the world chooses to fight wars in the atomic age. But it is possible to foresee a sneak atomic bomb attack that deceives the defenders until the moment the bombs begin to explode. There have even been some guesses that the country firing the bombs might not be immediately identified. That guess seems far-fetched. But it is not too far-fetched to speculate on the sneak attack attaining complete surprise.

With that attack, in one hour, all the cities of a country like the United States with populations of 100.000 or more might be destroyed. And with the cities about ten percent of the people of the nation could be expected to be killed.

Without complete surprise, some protection is possible to minimize immediate loss of life and of injuries. Shelters some distance from the center of the atomic explosion would afford protection. They would save men, women and children from some of the destruction that happened in Japan.

There men and women who were not killed and not seriously injured became bald on the tops of their heads. The baldness was due to radioactive rays. It affected the tops of their heads because they were outdoors, without benefit of air raid warnings, and the atomic bombs were exploded high in the air above them. Three feet of concrete would have stopped these rays from doing damage. The concrete would also have saved many Japanese from more serious and often fatal radioactive burns that damaged bone marrow, caused teeth to loosen in a few days, and frequently resulted in death from anemia. Shelters of this sort would also afford some protection against the heat and blast effects of an atomic bomb.

Laying these speculations aside, it is apparent that with atomic weapons the world has reverted to the type of war common thousands of years ago. Then the victor often destroyed not only opposing military forces but the entire enemy population of men, women, and children. Women were spared often as prizes and men as slaves. But with atomic war there may not be even such-diluted mercy.

The new weapons will certainly reach far over all military lines and all fixed defenses and fall upon the home folks, on mothers fathers, and the children wherever they are. In fact, it is possible that in an all-out atomic war the military forces may be one of the comparatively safe occupations, because they at least will be dispersed to the best advantage to avoid atomic weapons. It appears certain now that one nation will be able really to destroy another nation, and that even a great nation may not be secure from this fate. Whatever may happen in the future, this inherent power of atomic weapons is real, and that is probably the most sobering fact in all human history

THE SPLITTING ATOM

THE explosive uranium is not a scientific creation. It is like the discovery of coal and petroleum, just another natural resource in the earth. Nature created these uranium atoms with their ability to split, and they have been waiting for thousands of years for man to discover their peculiar qualities.

Plutonium, the new metal that is produced by alchemy in the state of Washington, is a scientific creation. But its properties are the same as those of uranium. In fact, after the war ended, the discovery was announced that plutonium exists in the earth. This new synthetic metal is, moreover, made out of uranium and therefore is limited in amount.

Uranium is mined like other minerals. Uranium ores are converted into metal much the same as other minerals. The first uranium metal appears to have been made immediately after World War I. No one then suspected its explosive properties. The metal was made in very small lumps about the size of buttons for experiment.

Actually this metal was non-explosive, because it was normal uranium—that is, a mixture of the atomic weights 238, the plentiful form of uranium, with a very small amount of the explosive 235 type. The first uranium metal made on a large scale came during World War II and cost at the rate of $1,000 a pound. In a year the price was reduced to $22 a pound. However, it is not necessary to use the expensive metallic uranium in order to obtain the 235 variety, either for bombs or for atomic fires. The 235 can be separated from compounds containing uranium.

The atoms of two other heavy metals split much the same as uranium. They are protactinium, which is so rare that it is not a present prospect, and thorium, which is three times more plentiful than uranium. These three atom-splitting metals hold the top places in mass among all the known natural elements. All three are slowly disintegrating. This does not mean that they are vanishing, but only that they are moving downward in atomic weights step by step until finally they become lead. This natural process of breaking down is, however, an important sign of the probability that no other atoms will split like these.

Little was said during the war about thorium. It was not then used for bombs or power. But the methods by which it can be used are known. When thorium is bombarded by neutrons, a new chemical element is created. This element is uranium 233. That is, the creation is a new metal with the atomic weight of 233. The atoms of this metal split the same as those of uranium 235. Thus for atomic energy the world possesses five metals, three of them natural, and the other two synthetic, namely, plutonium and uranium 233.

Except these five, the atoms of no other elements are known thus far to split in any way that yields either useful atomic power or bombs. The difference between these five and all the other elements is like the difference between coal and stones. When a fire is started in coal it continues by a chain reaction until the coal is consumed. Stones really can be burned, too, provided a fire is hot enough. But once started burning, stones do not continue by spreading fire from one stone to the next.

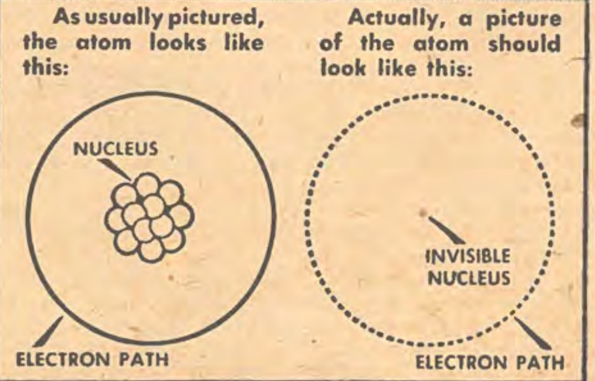
The talk about splitting atoms of other chemical elements is based on misunderstanding and wishful thinking. The others are wished for because they are cheaper and more plentiful. It is conceivable that more than forty of the other heavy elements may in theory be split like uranium. These are all the elements heavier than silver. They include tin, cadmium, iodine, tungsten, platinum, gold and lead. It is a fact that their atoms, if split, would each yield many million electron volts.

But the neutrons, or other particles, powerful enough to split these commoner elements are almost non-existent. The ordinary neutrons that split uranium have no such effect. Cosmic rays produce some particles with energies that might split gold or any of the other two score. But no one can make the equivalent of cosmic rays without prohibitive expense. And if they are made, there is still no chain reaction.

The cosmic ray projectiles have energies of many billions of volts. Contrast that enormous figure with the voltages of the neutrons that are most efficient in splitting atoms of uranium and plutonium. The latter carry only about one-fortieth of one volt.

Splitting an atom means that its core, or nucleus, breaks into two nearly equal pieces. That is all it means. What happens to the electrons circling around the core does not matter. When an atom splits, each of its parts becomes a complete new atom and both are among the known atoms of chemical elements.

The Misleading Atom


As usually pictured, the atom looks like this:

Actually, a picture of the atom should look like this:

THE nucleus of an atom is invisible. Even if an atom were as big as this page, it would take a microscope to see the nucleus, for the nucleus is only one ten-thousandth of an atom's diameter. Yet it contains 99 percent of the weight.

ATOMS ARE EVERYWHERE

IT is difficult to be told that flesh and everything else in the universe is made of atoms so small that no microscope has ever been able to see one. After accepting that, the simplicity becomes astonishing. All these atoms, of whatever sort and without any exception, are composed of only three kinds of tiny particles. The three are neutrons, protons, and electrons. The first two are heavy, each about 1800 times the weight of an electron. The only difference between the atoms of one chemical element and another is in the number of these particles. For example, the difference between an atom that gives an eye its blue color, and an atom of mercury, is merely in the number of particles. Eighteen of these primary particles make a carbon atom in your body. Three hundred and twenty-seven of them make an atom of the explosive uranium 235.

Although neither atoms nor their component particles, the electrons, protons, and neutrons, ever have been seen, all will form tiny trails in water vapor that are visible to the eye without a microscope. These trails are produced in an apparatus named a Wilson cloud chamber. The trail of each kind of particle is distinctive; that is, by use of electric and magnetic forces, each one can be made to identify itself. The particles can be seen to emerge from atoms, and to reenter atoms, or to bounce against atoms or each other like little billiard balls. These pictures were part of the knowledge that laid the foundation for the atomic age. Scientists have been watching and photographing the vapor trails for years. But among laymen almost no one thought there was anything practical in this scientific pursuit. In fact almost everyone who stopped to look or listen said "So what?"

"What" is the atomic bomb.

All the familiar diagrams or drawings of atoms are misleading. The atom has not any skin as some diagrams would indicate. There is just a blur of electrons moving at speeds of probably hundreds of thousands of miles an hour around a central core. In the next place and much more misleading, the central core is always visible in the pictures. But the fact is, if an atom was enlarged to be as wide as the diameter of this page, the central core of nucleus would be invisible without a microscope.

This core is so small that its diameter is only one one ten-thousandth part of the atom. Yet in this core is concentrated virtually the entire weight of an atom. The core is made of the two heavy particles, neutrons and protons. What force squeezes down the atomic core and all its mass to this small compass is unknown. The size, however, has been measured accurately. The forces of electrical attraction and repulsion in the squeezed-down core are known, but they do not explain the small size. There is another force in this incredibly small atomic core, which has been calculated, although its nature is still unknown. This mysterious force is something about one million times stronger than the force of gravitation.

The small size of these atomic cores is the principal obstacle to splitting them and to obtaining atomic energies by the split of the plentiful atoms. The particles whose impact splits atomic cores, namely neutrons, are no bigger than the core.

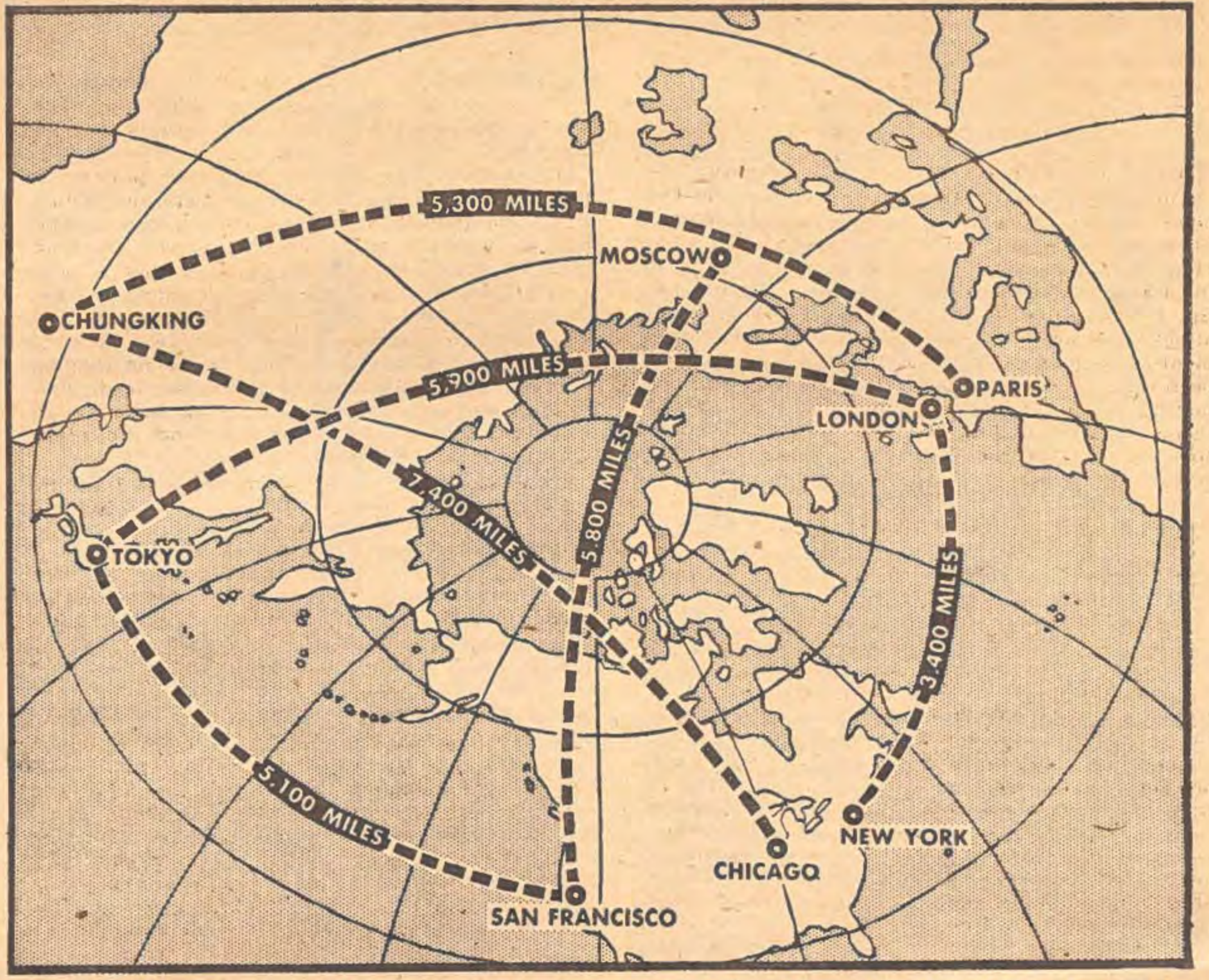
There is no way of aiming these atomic bullets. Consequently it is a fact that out of every one hundred thousand neutrons or other particles fired at a single atom, only an average of one is likely to hit the core. And that is just about the most wasteful shooting that man ever tried. That is why it has cost far more for the atom-smashing apparatus than the value of the energy which came out. That is one reason why the present uranium, plutonium and thorium atoms appear to be in a class by themselves, a natural phenomenon which is not likely to be repeated with any other atoms. These very massive atoms split and furnish their own bullets for further splitting at a cost that is cheaper than burning coal, oil or gas.

DREAMERS AND THE ATOMIC FUTURE

ATOMIC bombs are only one step toward a future whose outlines already were taking form when the war ended. This future is mapped partly by the men to whom nobody listened, the theoretical physicists. These men were called in on the bomb project to take their places with practical engineers. One of them is Dr. Robert J. Oppenheimer, who was head of the Los Alamos, New Mexico, project known in code as the Y. His men were the fabricators of the bombs.

Before the war, Dr. Oppenheimer one day was

The Arctic—Future Mediterranean Sea?



The atomic bomb, plus the development of long-distance airplanes and rocket ships, may make the Arctic militarily the most strategic region in the world, just as was the Mediterranean Sea in former times. This map shows how the earth's major cities all are relatively close to the north pole—all subject to atomic raids over the top of the earth. The figures shown are distances by air.

reading a paper on theoretical physics to a group of his colleagues at the Massachusetts Institute of Technology, Cambridge, Mass. A severe thunderstorm came up. Presently the chairman interrupted and apologized to Dr. Oppenheimer, saying:

"We should take a brief recess until the storm abates so that you can be heard."

"Oh," replied Dr. Oppenheimer, "was anyone listening?"

That describes the prewar place of theoretical physicists. They were the men nobody listened to. Scarcely even their own colleagues. Even to most of the scientific world the ideas of these men were closed books and their comments were dream stuff.

Nevertheless when atomic fires and bombs were needed, these dreamers took many of the top jobs among practical men. They, and almost they alone, could foresee the shape of things to come, and how those things must be handled to avoid the risk of blasting the bomb project and much of its personnel into fragments so small that there would be no trace. The accident record of the entire bomb project is almost miraculous considering that some risks were previously entirely unknown and in some respects the greatest that were ever faced.

It should be noted that the theoretical physicists were by no means the only executives of the project to be credited with the safety record. All through, in every area where the Army, the scientists and big industry worked, the precautions taken against accidents were about ten-fold those of the best ordinary safety practices. One reason for this was that the atomic bomb project could not afford many serious accidents, because had such occurred no power on earth would have been able to keep the secret.

These men to whom nobody listened went safely in almost one single stride into the mysteries of an energy greater than the sun is known to use. In fact, when these men started on the bomb work, they already knew how the sun produces its energy, and that its method would not work for their purposes.

The sun uses the millions of degrees of temperature of its interior to change four atoms of hydrogen into one new atom of helium. Involved are six pieces of alchemy, in which the sun starts with common carbon, changing it into nitrogen, then into oxygen, and back down the scale until it has its original carbon again, plus the new helium atom. This takes a long time, and out of it all comes about thirty million electron volts of energy. That is less than one-sixth of the energy which spurts from a single split of an atom of uranium.

What these dreamers know, and what their colleagues have verified in laboratory experiments, is a comforting guarantee that there is no way for man to explode the earth nor any part of it. They can and have demonstrated that it is not possible for the air to burn with atomic energy unless the volume of air should be as great as the entire mass of the sun at a sustained temperature of a million degrees or more. The total volume of air surrounding the earth would not make much more than one good tongue of flame of the sort that is continually shooting out of all sides of the sun.

Although the temperatures created by the explosion of an atomic bomb are many millions of degrees, and are about as high as those which have sometimes been credited to the interior of the sun, they are gone in a flash. They are not sustained. It may be difficult to refrain from the fear that these scientists have missed something when they say the air will not burn with atomic fires, but what they did with the atomic bomb is a good guarantee that their predictions about the safety of the earth are correct.

The only place in the entire universe where there is any sign of atomic explosions of an earth-shattering scale is in the stars called Novae. These are the so-called new stars which telescopes discover about once each year on the average. Sometimes they appear where no star was seen before. At other times a small star flares up to become very bright.

Hundreds of years ago one of these new stars was so bright for a short time that it could be seen in the daytime. So far as telescopes can observe, all of these explosions occur in stars. They do not so far as the evidence goes occur in cold solid bodies like our earth and the other planets of the solar system. While it is possible that the earth may have been created partly as the result of some atomic explosion billions of years ago, it is virtually certain that the explosion took place as a result of chemical reactions going on in millions of degrees of heat, and that by cooling down the earth lost the energy by which it could destroy itself, or by which man could blow up the world.

But it can be confidently expected that stories and theories about blowing up the world, or parts of it, will plague people for many years. The theories are not scientific. They are guesses, and are not made by scientists well founded in atomic work. One example is a proposal that the earth never lost its original heat, but that the high temperature retired into the supposedly molten interior. There it now awaits a deep enough crack in the crust, created by an atomic bomb, perhaps one exploded under water. Through this crack would issue the pent-up forces to blow the world apart.

REMAINING MYSTERIES

THE phrases "energy of creation" and "power of the sun," used to describe the tremendous force of atomic bombs, are in about the same class as the fairies, genii, ghosts and Olympic gods that earlier men used to explain natural events they did not fully understand.

Both explanations of the bomb mean that some of the forces of atomic energy are not yet understood. These mysterious forces are apparently some kind of attraction that takes place between very small particles when they are very close together. This is the force that has been calculated as a million times greater than gravitation. This force apparently does not apply in any large degree to objects as large as atoms. But it exists between the much smaller primary particles that form atoms, namely neutrons, protons, and electrons.

The existence of this odd force in the sub-atomic world is apparently the key that scientists expect to use to obtain atomic energies from elements that are more plentiful and less expensive than uranium and thorium. This plan will enable the investigators to bypass the difficult problem of trying to split other atoms in the same way that uranium and thorium divide. The theoretical physicists, the men who safely guided the atomic bomb development, already have definite plans for tapping the still unknown sub-atomic energies.

Cosmic rays have furnished the clues. These rays produce particles that are neither neutrons, protons, or single electrons. The particles are plainly visible in the vapor trails of cloud chambers. One of them has a mass equal to the weight of about two hundred electrons. It has been named meson and also heavy electron. The latter is a popular name which annoys the nuclear physicists, because it is an untrue description. Since the war mesons have been made in the laboratory by a 100,000,000-volt X-ray machine. Another particle that has been seen is made of two electrons, one negative and the other positive. This particular pair is probably the most amazing combination yet discovered. This one shows up as a result of a gamma ray converting itself into solid matter. A gamma ray is the same thing as an X-ray and as immaterial as light. This pair of particles appears to represent the creation of matter. Actually it is not creation, but only evidence of what scientists have long believed, that both matter and rays are merely two different phases of the same thing, that one is convertible into the other, and that both are indestructible.

Two other pieces of information about the sub-atomic particles have come to light, and have been emphasized by the atomic bomb work. These are that both of the heavy particles, neutrons and protons, probably are not units, but are assemblies of some sort.

The theoretical physicists already have predicted that still other sub-atomic particles exist, and have outlined the methods by which they may be discovered. Dr. J. A. Wheeler of Princeton University has sketched the picture of this future atomic energy trail. He is one of the younger theoretical physicists, whose ideas along with those of his former teacher, Professor Niels Bohr, the Danish scientist of Copenhagen, had much to do with initiating the atomic bomb project.

Wheeler likens the uranium discovery to Columbus landing on the islands of the West Indies. The uranium, protactinium, thorium, and plutonium atoms are only the outlying islands in the atomic age. He says the continent lies beyond. But this continent surely will be found and explored, and its resources are vast and unpredictable. He thinks that in the course of exploring this continent, man may find an explanation of an event that took place perhaps ten billion years ago. This event was the beginning of creation in its present pattern.

Scientists do not predict how much farther the atomic energy discoveries may lead man into the mysteries of creation, and in fact few of them venture as far as did Dr. Wheeler. But it is possible for speculations to go farther. The atomic predictions of today are not far out of line with some of man's age-long beliefs. As an example, *Genesis, 1-3,* reads:

"And God said, Let there be light; and there was light."

This sentence, if removed from the context, and considered by itself, comes close to one of the fundamental discoveries of physicists. It is only neces-

FOREIGN SCIENTISTS DID SPADEWORK IN ATOMIC RESEARCH

sary to substitute in the Biblical sentence the present day definition of light as verified in laboratory experiments.

In that new definition light is simply one of the forms of electro-magnetic radiation. It is one of the forms of energy. Light is the same sort of thing as heat, radio waves, X-ray, and the gamma rays of radium. The only apparent differences are in the wave lengths, or the frequencies of vibration. Some of these electro-magnetic waves have been seen to change into material particles in laboratory tests. If mass and energy are interchangeable, as the atomic bomb has proved on a big scale, then light also changes into matter.

Considered in this broad, although somewhat technical meaning, creation of light is the creation of matter and energy, and those two comprise all the material universe.

PIONEERS OF THE ATOM

MILLIONS thought Providence gave the Allies the secret of the atom. That is not true. If Providence had anything to do with it, she gave the secret to Germany.

What happened to this secret in the prewar thirties was something different than most people realize. An understanding of those events is almost as important to the world's future welfare as the atomic discovery itself. The atomic events of the five years preceding Hitler's invasion of Poland prove the impossibility of preventing further atomic energy discoveries. The world may be able to delay, but cannot stop the advance either in atomic power or bombs. Inevitably it will become easier to destroy with future atomic energies. Civilization may use intelligence to save or to advance itself, but cannot escape the discovery of more facts of nature.

Unveiling the secret of uranium began in Rome, in 1934, with some work by Enrico Fermi, now an American citizen. He is credited by many scientific leaders with inspirational insight. He was the first to use the then newly discovered neutrons to bombard uranium. He was seeking in this way to create out of uranium some elements that were heavier than this metal and not known to exist in nature. Fermi was not looking for the material to make atomic bombs. The evidence is he did not even think of that. What he discovered was a puzzle that interested scientists everywhere for the following five years.

Among those working on this problem were Madame Curie's daughter Irene, wife of Frederique Joliot. Both Joliots are in top ranks of physicists. They were not looking for atomic bombs. They found, in the uranium bombarded by neutrons, traces of chemical elements that ought not to exist there. But the identification was not clear.

Next, in Berlin, Otto Hahn, head of the great Kaiser Wilhelm Institute, undertook the investigation. He assigned the search to Lise Meitner. She is an Austrian. She had reason to fear the Nazis. Hahn protected her, but as the Nazi tyranny spread, she left Germany and went to Stockholm. Her work on the strange interlopers in uranium was unfinished. Hahn, who is himself a chemist, and his colleague F. Strassman, took over the Meitner data. Hahn noted some facts she had not finished interpreting and quickly made the discovery that one of the puzzling elements in the bombarded uranium was barium.

Barium is about half the weight of uranium. That was the all-important basic discovery. The barium meant that uranium atoms were splitting into two about equal-size atoms. That was the secret of the atomic bomb, although not apparently recognized at the moment.

Almost the first action Hahn took was to notify Miss Meitner in Stockholm. To do that was part of the code of scientists, and probably also involved a touch of chivalry, since Meitner, with the information, and what she might do with it, would be in a stronger position in her scientific career. The fact that Hahn's identification of the barium was the great discovery was recognized by the Nobel committee later in awarding him a Nobel prize, although not for this particular atomic discovery.

Perhaps it might be said that it was the work of Providence that Hahn and Strassman did not keep their discovery a secret for Germany alone. For, as will appear soon, when physicists in other countries heard of that barium discovery, they took only a few hours to discover the secret of bombs and atomic power. At any rate, Hahn and Strassman do not appear to have been looking for atomic bombs.

LISE MEITNER'S STORY

A WORLD-WIDE legend has grown up about Miss Meitner. She has been credited throughout the lay world with the inspirational insight that first explained what Hahn and Strassman discovered. But scientific reports never credited her alone. At the time, and before the world knew anything about it, she was credited jointly with her colleague, O. R. Frisch, who was another and earlier expatriate from Germany. Frisch later worked on the bomb project in England and then at Los Alamos, New Mexico, as part of the scientific team that made the bombs. Niels Bohr, of Copenhagen, in whose laboratory Frisch was working, urged Meitner and Frisch jointly to study the Hahn discovery.

Miss Meitner's own story, in a letter to The Associated Press, hitherto unpublished, gives joint credit. She writes:

"I want to establish the following points. Nobody had formed the uranium-splitting idea before the process actually had been found.

"When Professor Hahn and Dr. Strassman demonstrated that by irradiating uranium by neutrons, there were formed transformation products as low as barium, O. R. Frisch and I discussed this result and came to the conclusion that there was an absolutely new type of nuclear process, which on the basis of Bohr's liquid drop model of atomic nuclei could be explained as a division of the uranium nucleus into two smaller nuclei of roughly equal size.

"And we drew attention to the fact that by this division of the uranium nucleus a very large amount of energy will be set free. By rough estimates we showed that this energy was about two hundred million volts."

LITTLE DROPS OF WATER

IN their published report Meitner and Frisch said that the heavy nucleus of uranium would be expected to move in a collective way having some resemblance to a liquid drop.

There it was. Thinking in terms of little drops of liquid made clear the incredible thing that nobody had anticipated. Atomic bombs and atomic energy were clearly possible. But Meitner and Frisch had not been looking for any such outcome. Everyone is familiar with the model they had in mind. It is seen when water drips off an icicle, or off leaves. As the moisture extends down in a V-shape, the lower end pinches off, forming a drop. This pinching action is the way a drop of water breaks in two.

He Gambled on the Atom

FRANKLIN D. ROOSEVELT

Bohr and other physicists had theorized that the core or nucleus of a heavy atom is not a hard, rigid ball, but is more like a mass of jelly. This core, Meitner and Frisch reasoned, might have a surface tension like a drop of liquid, and so would be capable of dividing in two.

Frisch and Meitner were the first to publish this finding. But even had they kept silent, the great atomic discovery would not have been delayed by one day. Bohr came to New York before Frisch and Meitner had completed their studies. One evening he called at Columbia University, upon his colleagues there, George B. Pegram, dean of physics, and John R. Dunning, who later became one of the foremost atomic bomb men, and others of the Columbia group. Bohr told them of Hahn's discovery. One of the group picked up an old envelope. A few calculations were quickly made on its back. These showed the splitting of uranium with release of far more than a million electron volts. Dunning and some of the colleagues went into a laboratory, and in two hours had the evidence verifying the great release of energy.

The discovery was stunning. The Columbia group talked it over and decided to maintain silence awaiting developments. Bohr a day or two later informed other colleagues gathered in Washington, who quickly arrived at the same results as Columbia. These men from other scientific institutions conferred with the Columbia group, and it was jointly decided to make public what had been found. All the parties refrained from claiming credit for priority in discovery. Bohr told them he felt sure, as later proved to be the fact, that Frisch and Meitner had done the same thing a little earlier.

SCIENTIFIC PROGRESS IS INEVITABLE

THE trails of great scientific discoveries are frequently like this one. In fact, the discovery of bombs and atomic energy became inevitable back in 1932, the year that J. Chadwick of England discovered neutrons.

Scientific progress is moreover inevitable. If one nation misses making the discovery, the scientists of another are sure to do so. The discovery of X-rays by Wilhelm Konrad Roentgen, the German, is an illustration. The very day that his discovery was cabled to American newspapers, American physicists looked in their own laboratories and realized that they had been seeing the evidence of X-rays in their own experiments.

Attempts to restrict this scientific progress has two perils to society. One is for the nation that restricts its scientists too much. In some other nation, there is certain to be a group not so restricted. This second group is more likely to make fundamental discoveries. Such a group need not be composed of evil men, and possibly never will be. But it may be easy for evil men to take over what such scientists have learned.

Another danger is that if the investigation of atomic energy is shackled by too rigid controls, most of the rest of scientific progress will also be shackled. For the energies in the atomic nucleus will soon be vital parts of the progress of many other branches of science, and already are exactly that in medicine and biology and nutrition. Atomic energy is the chemistry of the future. It will be important in some of the things that the great 200-inch telescope will see. It is true that trained physicists and chemists will make most of the atomic discoveries. But for some time physicists and chemists have been indispensable members of the research teams in other sciences. The discovery that means the next great step in atomic energy might come from a group working in cancer or synthetic rubber, to name but two of many possibilities.

In the days when the atom bomb was a great secret, an American rubber chemist, reasoning in terms of chemistry instead of physics, had the idea that the mysterious action between very small particles is the key to atomic energy that will not have to depend on splitting atoms. He did not then know that physicists were thinking about this same concept. He wrote a letter to a physicist of his acquaintance outlining his proposals. This happened in war time when the exchange of scientific thoughts was not one of the freedoms. The only reply he received was:

"How in the world did you manage to get that letter through the mails?"

Industry also will be hampered in its progress if controls on the study of atomic energy are made too severe. Not only in power, but in many other ways this new atomic energy will become useful in producing those things that the public needs. A nation that voluntarily restricts its own atomic energy progress without the certainty that other nations are doing the same in full measure, will risk its own industrial and economic future.

There is another important aspect. The great discoveries often appear so insignificant when first reported that no one suspects their significance. And this aspect of science may be a safeguard for those nations or groups who go too far in attempting to shackle knowledge. No one, for example, would have thought to interfere with Dr. Max Planck, the

The Search for Atomic Secrets Began in Ancient Greece

ANCIENT

DEMOCRITUS, 400 BC, proposed theory of invisible particles.

ARISTOTLE, 350 BC, rejected idea, said there were 4 elements in all matter.

ARAB thinkers about 1000 AD added three more basic elements.

REBIRTH

DESCARTES, France, 17th century, said particle motion caused heat.

DALTON, England, 1808, established modern atomic theory in writings.

MENDELEEFF, Russia, 1869, set up periodic table of 92 elements.

MODERN

EINSTEIN, Germany, 1905, gave formula energy equals mass.

THOMSON, England, in early 1900's discovered electron.

RUTHERFORD, England, 1918, found proton, smashed first atom.

BOHR, Denmark, 1913, established electrons move in regular orbits.

FERMI, Italy, 1933, discovered neutron capture by nucleus, value of slow unit.

MEITNER, Austria, 1939, showed with Frisch that neutron splits U-235.

German physicist, in teaching his class of students about color temperature. Color temperature is a technical phrase. The light from a tungsten lamp is somewhat yellow, and the temperature of the tungsten filament is around 2500 degrees Fahrenheit. If a slightly blue-colored lamp bulb is used in place of the ordinary white glass, the light loses its yellow tinge and becomes more nearly white. This color, due to the blue glass, is the same shade that would be emitted by a tungsten wire heated to about 3600 degrees, that is, about 1000 degrees higher than the ordinary lamp temperature. That difference is the color temperature.

Professor Planck was teaching his students the mathematics by which such color changes can be predicted. He was using a new mathematical formula for this purpose. The new formula was only a fraction of a degree more accurate than the old, but scientists prefer to use the more accurate tools even though the differences are very slight.

Then the professor went on a vacation. While he was away he received a letter informing him that the new formula had worked very well in the temperature studies so long as it dealt with short wave lengths. But when applied to the longer wave lengths, the formula no longer had any agreement with the old one. Planck did not wish to interrupt his vacation. He wrote to the class telling them to multiply the last factor in the new color-temperature formula by —1. This was a shot in the dark by Professor Planck.

When he returned from vacation, he learned that the —1 had corrected the discrepancies. That minus factor, in fact, had worked far better than he had expected. So he was faced with the problem of explaining the realities behind this mathematical symbol. There just was no explanation in anything then known about the nature of light or of temperature.

But Professor Planck found one theory that could be an explanation. The trouble was that this theory was almost completely incredible. The theory was that light and temperature, instead of being smooth, uninterrupted streams of energy, as always had been thought, were broken up into small particles or packages that followed each other like the beads on a necklace. This was the now famous Quantum theory.

Professor Planck published it. No one really believed it at first. But after a time this Quantum theory explained so many things about energy that had previously been unsolved that the theory was accepted as a fact, and as the discovery of one of the great laws of nature. The Quantum theory became one of the corner stones in discovering atomic energy and making the bombs

'SALESMEN' OF THE BOMB

A FLASH of intuition by President Franklin D. Roosevelt gave the atomic bomb and the atomic era their practical start. Without his early inspiration, the atomic age would hardly have dawned before the war ended, and possibly not for years.

One man who is not a scientist was, more than any other individual, responsible for the President's initial action. He is Alexander Sachs, New York economist, with offices in Wall Street. Sachs is Russian-born, but American by upbringing, education and career. Some acquaintances say he looks like Ed Wynn, the comedian. He had known Roosevelt since 1932, and had been an informal adviser. He had no official government position, but some of his ideas had been acted on by the President. Sachs proposed in 1933 the use of N.R.A. funds for reconditioning the Navy, mechanizing the Army and improving the national defense. In 1936 he proposed the idea of a power pool.

By the time of the atomic discovery, Sachs had come to be known as the Economic Jeremiah.

He was one of a small group. all the others scientists and interestingly enough all of them foreign-born, who more than anyone else foresaw the dangers from the first. American scientists at that time were not accustomed to working with the government. The foreign group had a different background and with it a perspective to see that the government was needed

Professor Albert Einstein of relativity fame was one of this group All except Einstein were comparatively young. Sachs then was 46. The others were Dr. Leo Szilard, 42. recently arrived from Hungary; Enrico Fermi, 39, from Italy, at Columbia University; E. P. Wigner, 36, from Hungary, at Princeton; Edward Teller, 32, from Hungary, at George Washington University; and Victor F. Weisskopf. 31, from Austria. at the University of Rochester.

The early attempts of scientists to interest official Washington had got nowhere. The first attempt came within three months after the German atomic discovery, when Dr. George B. Pegram. dean of physics at Columbia, sent Enrico Fermi to Washington Fermi returned with the answer that the men he talked with were interested. That was all.

The motive of all the scientists was based on fear of what aggressor nations might do to the United States with atomic bombs. The small group of foreign-born stuck to their guns.

EINSTEIN LOOKS AHEAD

EINSTEIN discussed the prospects with Wigner and Szilard, and then with Sachs. The upshot was that in August, 1939, Einstein wrote a letter to Roosevelt and entrusted it to Sachs. The latter presented the letter to the President on October 11, along with scientific articles, a letter by Szilard, and his own observations. Einstein's letter read:

"Some recent work by E. Fermi and L. Szilard, which has been communicated to me in manuscript, leads me to expect that the element uranium may be turned into a new and important source of energy in the immediate future. Certain aspects of the situation which has arisen call for watchfulness and, if necessary, quick action on the part of the Administration. I believe therefore it is my duty to bring to your attention the following facts and recommendation.

"In the course of the last four months it has been made probable—through the work of Joliot in France as well as Fermi and Szilard in America—that it may become possible to set up a nuclear chain reaction in a large mass of uranium, by which vast amounts of power and large quantities of new radium-like elements would be generated. Now it appears almost certain that this could be achieved in the immediate future.

"This new phenomenon would also lead to the construction of bombs, and it is conceivable — though much less certain—that extremely powerful bombs of a new type may thus be constructed. A single bomb of this type, carried by boat and exploded in a port, might very well destroy the whole port together with some of the surrounding territory. However, such bombs might very well prove to be too heavy for transportation by air."

Einstein's letter went on to point out what might become a precarious situation in a race for supplies of uranium with Germany sitting in the driver's seat. He said that Germany already had stopped sale of uranium from the then best known source of supply, in Czechoslovakia. and told of uranium splitting work going on in Berlin under close observation of the government.

Szilard's memorandum pointed out the possibility of using uranium to drive boats and airplanes. He forecast too how bombs might be made

THE PRESIDENT'S FORESIGHT

SACHS gave the President the scientific manuscripts. But in his own discussion he emphasized the broad world trends. One was the possibility of the Nazis overrunning continental Europe and attacking England. If, he said, the Nazis succeeded in taking France, there would be no continental staging area for defense purposes. He remarked on the peril for England when only the English Channel stood between her and Germany.

"If," he added, "Hitler produces atomic bombs, the Atlantic Ocean will become only an English Channel for America."

Sachs also read the President the following passage from F. W. Aston, British scientist, who discussed the opposition to atomic research, saying:

"There are those about us who say that such research should be stopped by law, alleging that man's destructive powers are already large enough. So, no doubt, the more elderly and ape-like of our prehistoric ancestors objected to the innovation of cooked food and pointed out the grave dangers attending the use of the newly discovered agency, fire. Personally, I think there is no doubt that sub-atomic energy is available all around us, and that one day man will release and control its almost infinite power. We cannot prevent him from doing so and can only hope that he will not use it exclusively in blowing up his next door neighbor."

"Alex," remarked the President, "what you are

AMERICAN SCIENTISTS GAMBLED WITH THEIR OWN FUTURE

after is to see that the Nazis don't blow us up."

"Precisely," replied Sachs.

The President then called in his aide, the late General E. M. (Pa) Watson and said: "This requires action."

Sachs went out with General Watson, whom Roosevelt appointed as liaison for the White House. The President designated Dr. Lyman J. Briggs, then director of the National Bureau of Standards, to constitute a committee to consider the situation. This committee met at the end of October with representatives of the Army and the Navy as members, and a number of scientists. Some of the scientists were unconvinced. They suggested waiting and seeing, and said that lines of progress other than chain reaction might be more attractive.

"Let's wait" seemed to be the most frequent watch word during that first winter of the war. Military men would say to General Watson:

"Well, this is so remote. Let's wait and see."

General Watson sometimes replied, "but the Boss wants it, boys."

THE UNIVERSITIES GO TO WAR

MEANWHILE much scientific progress was under way in university laboratories particularly at Columbia. But Einstein and Sachs remained dissatisfied through the winter. In the spring, before the fall of France, Sachs saw the President again to talk about the probable course of Nazi aggression. Einstein wrote another letter with further information about progress of German uranium work. Szilard wrote a letter suggesting that a bomb set off at sea near the coast might produce tidal waves that would destroy coastal cities. He told of the possibilities of a new poison gas made of neutrons that might kill a human being within a radius of one kilometer.

Sachs urged the President not to be misled by the reticence of scientists. He proposed that the time had come to telescope into a short space the developments that ordinarily would take many years.

In June, 1940 the President set up the National Research Defense Committee under Dr. Vannevar Bush. This later became the Office of Scientific Research and Development. The new committee took over the atomic project. There it remained until the middle of 1942, when the Manhattan District was formed and Major General Leslie R. Groves took over.

The President, when he created Bush's organization had carried the ball for seven months. How much faith in science this required is shown in his word to Dr. Briggs.

"This baffling and intricate matter," was the President's description.

Einstein shyly remained away from all the Washington conferences. His role was to point out the cloud on the horizon. Sachs was the catalyst.

Under the new scientific organization, something new in war developed. This was the voluntary linking of the nation's universities and colleges to do a military job. What they did is probably the greatest single military revolution of history. The chain of universities stretched from coast to coast and Canada to the Gulf of Mexico. Canadian and English universities joined in some of this work. Columbia did the path-finding research of this period.

In those days American colleges and universities were the ports of missing men. Professors and scientists were not to be found by visitors who asked for them. They had departed. Where to? War work was the answer. Occasionally a guess was added that they had gone into atomic energy projects.

American industrial laboratories also lost scientists to bomb work. A few of these laboratories became atomic energy centers. This nuclear energy snowball rolled and rolled until it became the largest single war project. The Navy was in almost from the start with a project of its own that finally became one of the four methods of obtaining explosive atoms.

From Denmark came Niels Bohr, the father of the present conception that an atom is a small central sun surrounded by electrons in orbits like the earth and the other planets. The figure of Bohr looms big. He had been the teacher of many of the physicists of all nations. These former students included some of the leaders in the atomic energy project both in the United States and abroad. Bohr was one of the first to predict that it was not common uranium that was splitting but U-235.

Later, after he escaped from Copenhagen to Sweden with Hitler at his heels, and then was flown by bomber by the British to London, Bohr came to the United States under the code name of Dr. Baker. Here he acted as an advisor on the atomic bomb.

The volunteer scientists included some of the world's greatest and most famous. For nearly all of them there was one great driving force—deadly fear. Almost to a man they regretted what they had to do. Probably unanimously they hoped the result would be not simply the use of atomic bombs and energy but the end of war.

ONE PANAMA A YEAR

IF RED grains of sand were scattered over all the seashores of the world, and each grain were on an average about 200 yards away from every other grain, that would parallel the spread of explosive uranium 235 atoms in the earth.

If these red grains would explode whenever a few pounds were gathered together, it would have been easier to make the first bomb by gathering such sand, by hand, one grain at a time, using as pickers the half million workers who at one time or another were on the bomb project, than it was to gather enough atoms of uranium 235 to make the first bomb. The tasks of engineers and scientists in designing plants to extract the explosive material almost surpasses imagination. What they did is a guarantee that many things which seem like dreams will come true in the atomic age.

The equivalent of one Panama canal a year was built for nearly three years at Oak Ridge, Tennessee, where the uranium 235 was produced, and at Hanford, Washington, where the new explosive metal, plutonium, was made. When these plants were completed, the output per day was in pounds. The exact amounts were military secrets. By all accounts, the uranium output was higher than the plutonium. Two great plants, each in a separate valley, were built at Oak Ridge to produce uranium 235. A third large plant was built in another Oak Ridge valley for experimenting with plutonium. Four huge plants were built at Hanford.

In the driver's seat for the two billion dollar project was Major General Leslie R Groves, a six-footer, variously known in the Manhattan Engineer District by the code names of The Lone Ranger, The Headless Horseman, Gus, Gen, Ninety-Nine and other code names, less elegant, but intended affectionately. Ninety-Nine came from an airport messenger's mistake in copying the initials G.G., for General Groves, as 99.

General Groves is an Army engineer, fourth in his class at West Point in 1918, the son of a Presbyterian minister of Albany, N. Y, who was an Army chaplain. Groves is heavy-set, with thick, slightly greying black hair, blunt, firm and with eyes that usually twinkle. In taking over the atomic project, he gave up the chances for advancement that go with wartime military achievement for the greatest gamble in history. Could bombs be made at all? And, more critical still, would they be in time? Nobody knew.

If American science and industry failed the job might be the greatest hoax of all time. The American people might be so disgusted that the project could not be completed after the war. Science might be set back for years.

General Groves had a flare for saving difficult situations. In the early days, when the town of Oak Ridge was building a new dwelling every thirty minutes, on an eight-hour day, it became urgent to get the State of Tennessee to improve the roads to Knoxville, about twenty miles away. The situation was a bit embarrassing because the military authorities had not completed their liaison with Governor Prentice Cooper.

As the Governor tells the story, soon after the Manhattan District took over 59,000 acres of Tennessee, he received protests from about fifty families in the area who said they were being dispossessed from their homes hurriedly, and that it was up to him to do something about it.

A number of inquiries came from Tennesseans who said that their ancestors first brought fire into those valleys, where the families had continuously lived ever since. They asked why an outfit calling itself The Manhattan Engineer District should be taking such large quantities of Tennessee land from the tax rolls without identifying itself even by name or otherwise with Tennessee. Others pointed out that through the Tennessee Valley Authority's acquisition of land and otherwise the Federal Government had already deprived Tennessee of six per cent of its land as a tax source. Reports reached the Governor from Knoxville, from citizens ordinarily reliable, that the Oak Ridge development was not a military project at all, but had to do with a post-war social experiment and planned economy for some hoped-for ideal community.

At about this time an officer was sent to see Governor Cooper. This officer was under security restraint, and could not give the Governor any idea of the nature of the project, not even so much as a hint as to the general objective. This was not satisfactory to the Governor. General Groves then stepped in, along with Colonel Kenneth D. Nichols, the General's right-hand man. They invited the Governor to a meeting, offering to go to Nashville. The Governor suggested Knoxville, and the meeting was held there with the State Highway Commissioner attending, since the road situation was urgent. The Governor was satisfied with explanations, and the party started for Oak Ridge.

A state police car led the way. In the second car were the Governor and the General. While topping a hill, around a curve, the police car, with its siren blowing, passed a heavy truck loaded with a road scraper. The officer waved the truck to take one side of the road. The machine's startled driver swerved it completely over the edge of the road and down a precipice. The driver jumped to safety.

The Governor's car jammed to a quick stop, and he stood at the roadside looking down on about $4000 worth of ruined state machinery. General Groves went to see that no one had been hurt and then ranged himself beside the Governor, gazed down at the toppled machine and was the first to speak.

"You see, Governor," he said, "that's what we have been talking about. These roads are too narrow."

Later, at tea in Oak Ridge, Governor Cooper smiled—"General, it was not necessary to order a man killed and thousands of dollars of equipment damaged in order to impress us that a road was needed."

General Groves grinned, and throughout the project the Governor and the State granted every request of the District, starting with widening the roads.

"JULY 1ST NOTHING"

THE diplomacy of Colonel Nichols was an asset. He is a native of Cleveland, a graduate of West Point, in 1929, fifth in his class. Some of the younger scientists at Oak Ridge, immediately after the war, were debating how they should go about telling the country their opinions of the political implications of the atomic bomb, as they, and other scientists throughout the project, afterwards did. When it was suggested that they discuss the matter with Colonel Nichols, one of them replied, in effect:

"Not on your life. He will be so nice about it that he probably will persuade us to remain silent."

On many a day General Groves and Colonel Nichols sat for hours with scientists or engineers, or both, asking for the earliest possible date for completing a job. The scene often went like this:

"Well, General Groves, the best that can be done is July 1st."

And then from the General: "July 1st nothing. It will be done March 1st."

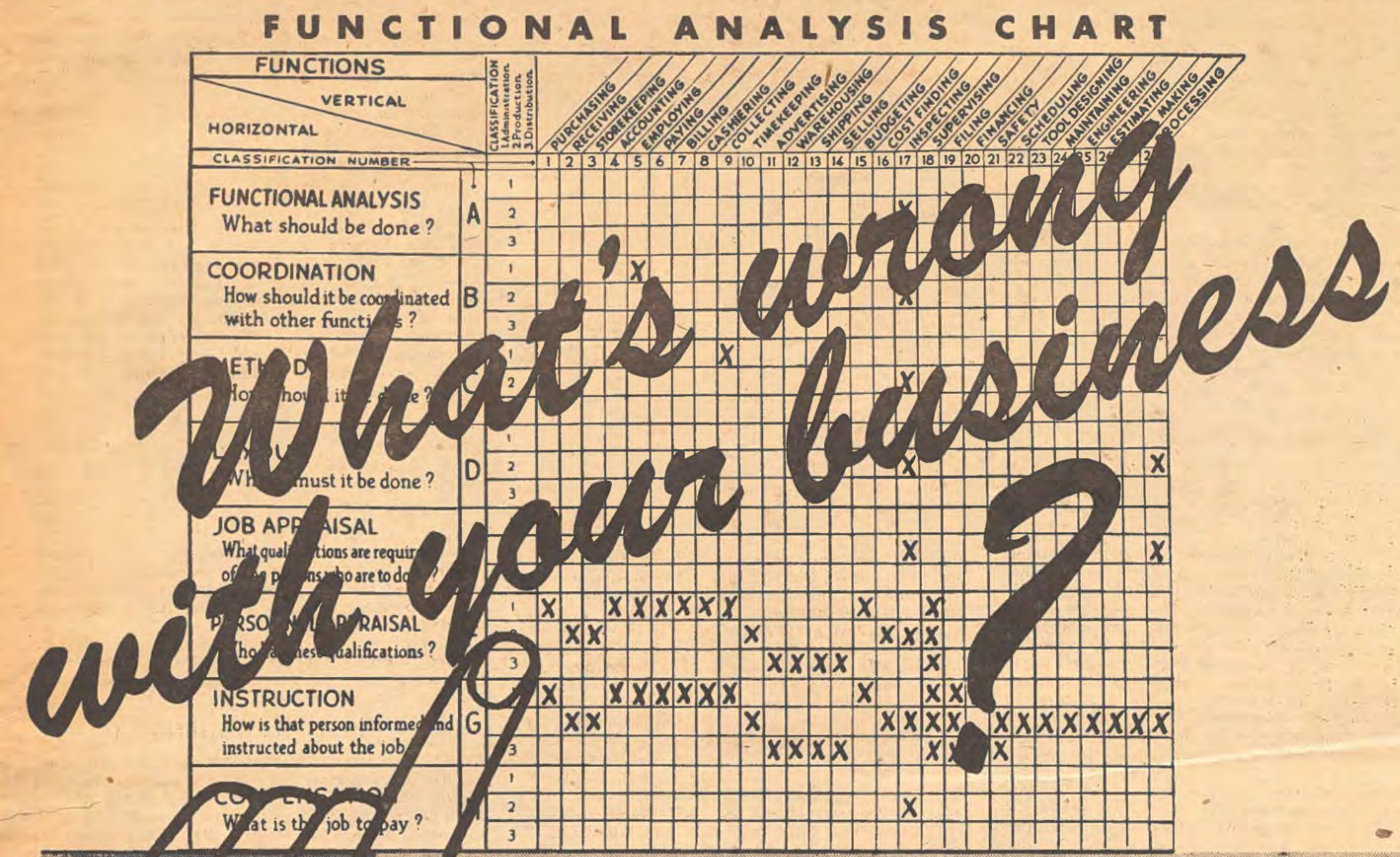
Time was running out, even when the great building projects started. One of these comprises about ninety buildings on the broad floor of a valley. These structures rise against a background of the Cumberland mountains looming six thousand feet high. But the mountains do not dwarf the great buildings of brick and concrete. The central building is U-shaped, each leg nearly a half mile long. The structure rises sixty feet. In this great building uranium that has been converted into a gas is strained through thousands of great barriers, containing billions of holes averaging a few millionths of an inch in diameter. These barriers are in the form of large, thin sheets. There are so many that if the sheets were set end to end, they would reach from New York to Tokio. This process separates atoms of weight 235 from the slightly heavier and far more numerous atoms of weight 238. The latter do not make bombs.

Nothing about this great plant now suggests the heartbreaking obstacles of its early days. A group of physicists at Columbia University in the early days were the plant's principal sponsors, under the leadership of John R. Dunning. Two of the head committees on the atomic bomb project were not favorable.

The project had a low rating until the DuPont Company was asked to build and operate the plutonium plant in Washington. The DuPont executives were granted the privilege of learning what the other projects were. They wanted to be sure that they were not undertaking something that would get them into trouble after the war.

They did not want to risk repeating their experience after World War I, when the company was accused of being one of the world's munition makers profiting from war. That accusation was made notwithstanding the fact that barely three

(Continued on Page 16)


FUNCTIONAL ANALYSIS CHART
FUNCTIONS
VERTICAL
HORIZONTAL
CLASSIFICATION NUMBER
CLASSIFICATION 1. Administration 2. Production 3. Distribution
PURCHASING
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ACCOUNTING
EMPLOYING
PAYING
BILLING
CASHIERING
COLLECTING
TIMEKEEPING
ADVERTISING
WAREHOUSING
SHIPPING
SELLING
BUDGETING
COST FINDING
INSPECTING
SUPERVISING
FILING
FINANCING
SAFETY
SCHEDULING
TOOL DESIGNING
MAINTAINING
ENGINEERING
ESTIMATING
MAKING
PROCESSING
FUNCTIONAL ANALYSIS What should be done?
A
COORDINATION How should it be coordinated with other functions?
B
METHODS How should it be done?
C
D
What must it be done?
JOB APPRAISAL What qualifications are required of the persons who are to do it?
PERSONNEL APPRAISAL Who has these qualifications?
INSTRUCTION How is that person informed and instructed about the job?
G
COMPENSATION What is the job to pay?
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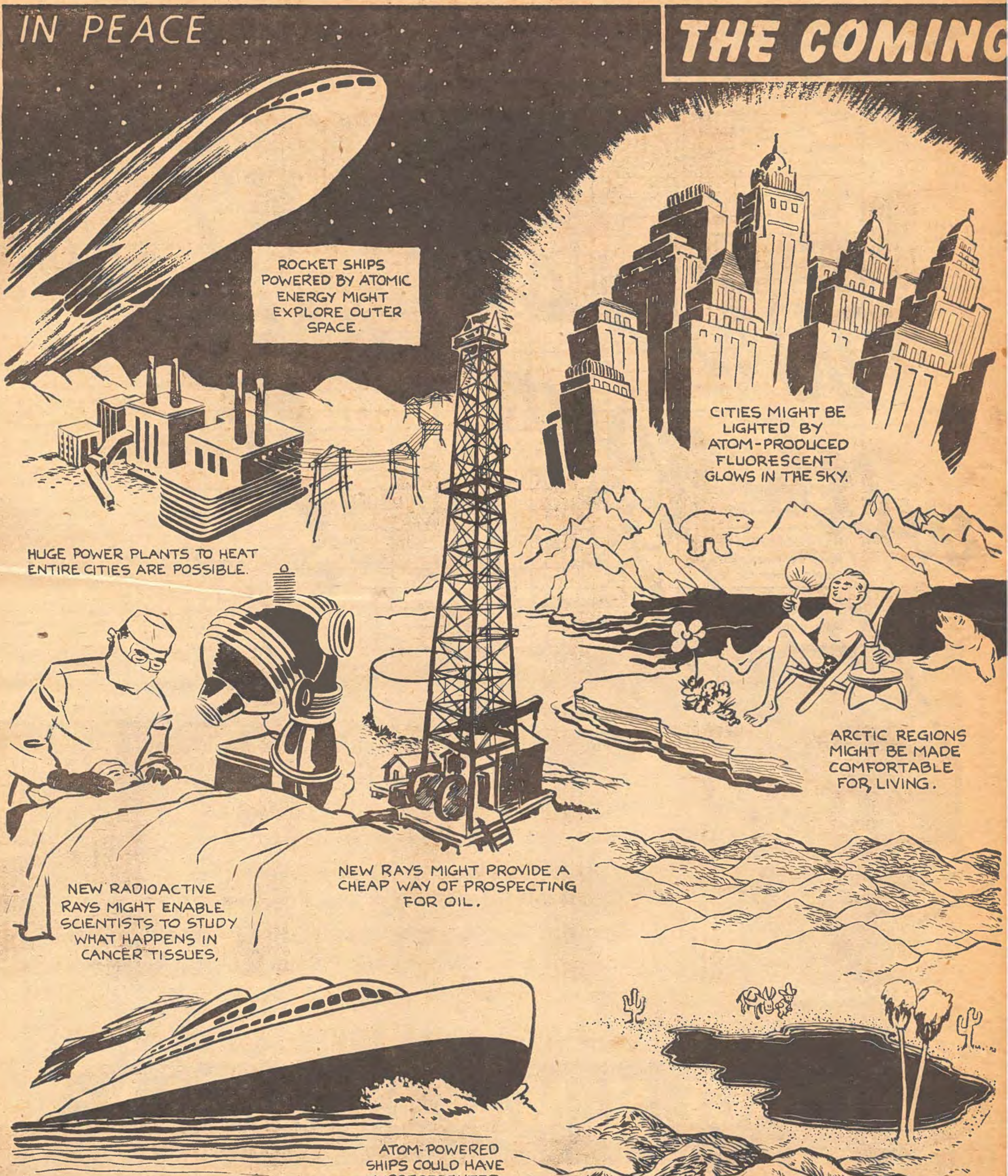
IN PEACE . . .

THE COMING



ROCKET SHIPS POWERED BY ATOMIC ENERGY MIGHT EXPLORE OUTER SPACE.

CITIES MIGHT BE LIGHTED BY ATOM-PRODUCED FLUORESCENT GLOWS IN THE SKY.

HUGE POWER PLANTS TO HEAT ENTIRE CITIES ARE POSSIBLE.

ARCTIC REGIONS MIGHT BE MADE COMFORTABLE FOR LIVING.

NEW RAYS MIGHT PROVIDE A CHEAP WAY OF PROSPECTING FOR OIL.

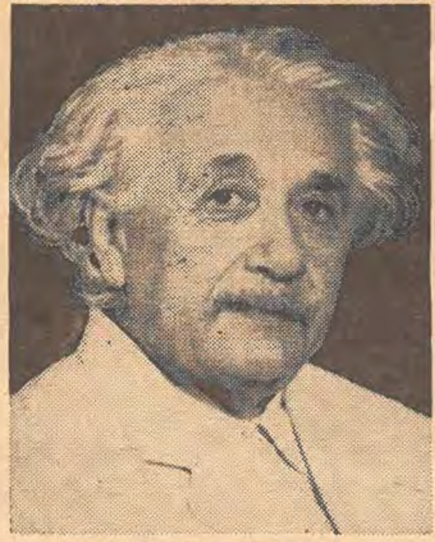
NEW RADIOACTIVE RAYS MIGHT ENABLE SCIENTISTS TO STUDY WHAT HAPPENS IN CANCER TISSUES,

ATOM-POWERED SHIPS COULD HAVE UNPRECEDENTED SPEEDS — AND SUBMARINES COULD REMAIN UNDER WATER LONGER AND TRAVEL MUCH FASTER.

LAKES MIGHT BE CREATED IN THE MIDST OF DESERTS.

ATOMIC AGE?

Three Who 'Sold' the Atom to America


DR. ALBERT EINSTEIN

DR. ALEXANDER SACHS

DR. LEO SZILARD

percent of the company's business was munitions. When DuPont engineers and scientists went to Columbia and looked at the gaseous diffusion project they were impressed. Their backing gave this project real impetus.

But after the construction started at Oak Ridge General Groves received letters declaring that it probably would fail. As the last straw, after this plant was well under way a group of foreign engineers, collaborators on the bomb project, arrived in this country and urged abandonment of this great division. General Groves stuck, spending more and more money on gaseous diffusion. Harold Urey, who received the Nobel prize for discovering heavy water, headed the scientific group in the gaseous diffusion plan. Dr. Dunning had enthusiastic faith in the plan and drove it through. In the end this plant produced more of the explosive bomb materials than any other part of the project, either for uranium or plutonium.

This great plant developed an efficiency surpassing that of most industrial plants. The development engineer was P. C. (Dobie) Keith, of the Kellex Corporation. Keith was one of the brilliant workers. When the plant was completed, and in operation by the Carbon and Carbide Chemical Corporation, he took his leave of Colonel Nichols, the Oak Ridge commanding officer. What Keith said in that farewell was typical of the effort of all key men. "I'm leaving," he said. "My job is done. I have spent four years. I think I have done good work. I can't help but wonder whether I was right—whether it will be in time. Do you think I made a mistake?"

Colonel Nichols, under security restraint, replied simply "No." A few days later the first bomb was exploded and the atomic age dawned.

SEPARATING URANIUM

IN a second valley at Oak Ridge was another great plant where a different drama was played. This plant comprises one hundred and forty buildings, dominated by mile-long, parallel rows of great, red almost windowless structures. In these, uranium is separated in vacuum spaces between the jaws of electro-magnets, whose pole faces are as wide as a small room, and wide apart. Uranium in the form of a gas is driven in the vacuum at high speed into the magnetic field between the great pole faces. Being electrically charged, the atoms curve in the magnetic field. The heavier atoms travel in wider curves than the light and separation is obtained.

So great are the magnets in these plants that a large amount of United States Treasury silver was borrowed from its West Point storage place and converted into the necessary electrically conducting bars. Copper, which normally would have been used, was not available because of other war needs.

In the beginning this process was a poor relation among all the brilliant schemes. General Groves was advised it wouldn't work, that it was as foolish as picking a needle out of a haystack, magnetizing it, and using this magnetic needle to draw one needle out of a second haystack. Opponents were many, advocates few. The General spent a hundred million dollars in the face of a growing file of adverse reports from scientific and engineering authorities that would have been damning had the plan failed.

The military policy committee of the project gave the General full support in backing the brilliant young scientist, Ernest O. Lawrence, who headed the magnetic separation idea. Lawrence received a Nobel prize for his invention of the cyclotron. In his University of California laboratory, Lawrence and his associates dismantled their cyclotrons to obtain great magnets for their experiments.

The magnetic plant was the first to produce uranium 235 in quantity. Although the output was not as large as the gaseous diffusion production, it came in handy at a critical time when the high purity uranium 235 was badly needed for early developments. The Tennessee Eastman Corporation operated this plant with a personnel of about 24,000. Westinghouse and Allis-Chalmers supplied much equipment.

A third plant, in the same valley with the U-shaped building for gaseous diffusion, was sponsored by the Navy under direction of P. H. Abelson of the Naval Research Laboratory. Here uranium was used in liquid form. The liquid was heated so that one portion was hotter than another. The lighter weight atoms moved toward the hotter part of the liquid, and in this way the 235 was separated from the 238.

These Oak Ridge plants, in their know-how and the new devices employed in them, were the second secret of the atomic bomb.

COOPERATION PAYS OFF

ONE of the early decisions by General Groves was to set up a plant at Los Alamos, New Mexico, to manufacture atomic bombs. Here also there was difference of opinion. One of the American scientists, some of whose ideas were part of the main success of the atomic project, advised there was no hurry. The making of a bomb, he said, would be a small job that twenty scientists could do in three months. Others thought it a bigger job than that. General Groves chose an early date and the bomb-making required two-and-a-half years and about 4000 scientists and technicians.

The scientists were not the only important men in the atomic project. Industry did a job as big, and the American industrial system showed itself as a further guarantee of bringing about nuclear miracles of the future.

The cooperation of industry never ceased to intrigue Manhattan District officers. In all far more than ten thousand firms cooperated, directly or indirectly. Some of the more prominent were asked to do things or make things that had never been done or made before. Nobody replied, "It can't be done."

The usual reply was—"If it can be done, we'll do it." They always did. The head of a great corporation signed a contract to make something heretofore unknown in industry, without even inquiring what the new thing was to be. After the war, when the project came out into the open, Manhattan District officers expressed admiration for the ability of free American industry to get things done.

Labor was a part of the great cooperation. Unions refrained from sending organizers into the great plants, because of the risk to secrecy inherent in any contact that required talking with those workers. When Chicago had a truck-drivers strike in 1944, many shipments of the atomic bomb project would have been tied up. The agents of the Manhattan District knew always where every carload was every day. They went to union officials. Without being able to tell these officials anything about the nature of the project other than that it was military, the agents were able to drive trucks to transship all bomb materials. Picket lines offered no interference.

The men in the planning divisions worked as continuously as they could stand. Fatigue often became a serious problem. It did not help much that the men at Oak Ridge who knew what was going on refrained from talking even to their wives about their work. In theory the wives did not know. Nevertheless, it was the women of Oak Ridge, living in mud, queues, and often in cramped quarters the like of which they never had seen, who were given by the Army officers a goodly share of the credit for the success of the project.

The wife of a famous scientist, whose work involved the bringing in of many other scientists and their families, had a tactful formula. Frequently these scientists did not go first to Oak Ridge. The first move was to induce them and their wives to give up comfortable homes and move to the wartime uncertainties of another city where they had to do important atomic energy work. This lady would talk to the wives about the importance of getting their husbands to take the first move. Later, after they had been thus softened up, she would repeat the tactics when the men folks were needed in an unknown new town that in those days lacked almost everything a woman values in a home, except only her husband and children.

Most of the men carried through despite fatigue. Colonel Nichols and his officers made a point of watching for the signs of exhaustion. These were not greatly different from some of those apparent in battle fatigue. They were never allowed to go so far as that, since sharpness of judgment was essential to these men. When one of them began slowing down, the usual remedy was to take a few days rest in the attractive hospital that the Army erected for Oak Ridge.

Although it was not one of the aims to make Oak Ridge an example of a post-war community, this fifth city of Tennessee became in some respects a prototype of cities of the future. Its dwellings were spread along, around, and sometimes behind the hills that form the valley, which is the main town site. Oak Ridge has the dispersion that has been a dream of the city of the future. As one result of this, Oak Ridge would not be totally destroyed by one of its own atomic bombs.

ATOMIC FIRES

IN the atomic energy prospects the cheerful side far exceeds the gloomy aspects. Atomic energy will some day raise living standards so that man who now in industrial countries has the equivalent of 80 slaves may be served by the equivalent of 800 or 8000 slaves in the form of mechanical, industrial, and economic improvements.

Men always have possessed the means of killing each other. First perhaps were the stone axes. Later came bronze implements, then steel, then gunpowder. When Alfred Nobel invented dynamite, he and a good sized group of philosophers believed that this explosive was so terrible that it would end war. Men now possess pistols for almost personal use. Man has never yet destroyed himself, although with some of his weapons he might have come close to that. Good sense and increasing intelligence have saved him, and these same qualities certainly will be used again now to reap benefits, instead of destruction, from atomic energy.

For the good things in prospect in atomic energy man will use atomic fires. These are somewhat different from atomic bombs in their make-up. They use neutrons for their burning, but in a quite different way than do the bombs.

An atomic fire is simpler than a blaze of wood, coal, oil, or gas. This nuclear fire would be easier to build, except for the great weight of materials that have to be used. The first great atomic ovens were erected in the State of Washington in a subdivision of the Manhattan District known as the Hanford Engineer Works. The location is 400,000 acres in the central part of the state between the Yakima Range and the Columbia River. This area is on an undulating table land in a mostly uninhabited region of grey sand, grey-green sage brush and dried water courses. Colonel Franklin T. Matthias commanded this project.

Here are three atomic ovens. Each is an immense cube of graphite bricks. The cubes rest on concrete foundations. All around each are shielding walls three feet thick, and over them roofs of the same massive proportions. These ovens are called piles because their bulk is mostly the pile of graphite brick. Hundreds of horizontal holes pierce the graphite cubes. These holes are machined with the precision of rifle barrels. The holes are really the ovens. When an atomic fire is wanted, slugs or blocks of normal uranium metal are placed in the holes. At Hanford this uranium is enclosed in aluminum cans. The cans, however, are for a special purpose not related to making an atomic fire.

When a sufficient number of blocks of uranium is in the holes, the fire starts. No lighter of any

(Continued on Page 18)

What they did they aren't telling . . .

The above picture shows a notable moment in the history of research in the Chicago area. A. L. Conn, representing a special Research Department group from the Whiting, Indiana, laboratories of Standard Oil Company, has just received a framed certificate from Dr. Robert E. Wilson, chairman of the board of the company.

The certificate says:
An Award for
Chemical Engineering Achievement
to
Standard Oil Company (Indiana)
In recognition of its unique
and meritorious contribution
to the
Atomic Bomb Project.

A great military and industrial accomplishment made possible by a patriotic pooling of the scientific knowledge and engineering experience of American industries and universities in the research and development, design, construction and operation of manufacturing facilities
under the direction
of the
Manhattan Engineer District
Corps of Engineers, U. S. Army
Presented by
Chemical and Metallurgical Engineering
February 26, 1946.

Dr. Wilson had earlier gone to New York to participate, with the heads of many other companies which had a part in the atomic energy work, in a ceremony at which Chemical and Metallurgical Engineering's seventh biennial award for chemical engineering achievement was divided among them. As this picture was taken he had just passed the certificate on to Conn and his co-workers. Others at the table, specially interested in the ceremony, were (left to right) J. K. Roberts, general manager of research for the company, Dr. Harold C. Urey, Nobel prize winner and a leader in atomic bomb research, A. W. Peake, president of the company, Dr. R. E. Humphrey, former head of the company's manufacturing and a famous chemist, and Dr. M. G. Paulus, vice president in charge of the company's manufacturing.

Teamwork for the Nation's Benefit

Much was said at the dinner about atomic energy in general, but not one word about what the Whiting research workers did. That is still a secret.

Whatever it was the Whiting researchers did about the atomic bomb, it was only a small part of what all American industry did. The significance of the picture is not so much therefore in the fact that Mr. Conn and his co-workers had done something to make the atomic bomb possible, but rather in the fact that they were available to aid when the nation needed them.

When the armed forces suddenly needed scientific work of an unusually high order, the laboratories of American industry, developed in a competitive economy under a system of free enterprise, stood ready to do the job. Technical skills built up through years of research were available. No comparable job was done in the government-dominated laboratories of any totalitarian power. As General Groves pointed out, "the development of the atomic bomb was a national undertaking, a job requiring the best scientists of our leading universities, the know-how of industrial laboratories and engineering management, the technical skills of American workers and the military and engineering knowledge of the armed services."

Architect's drawing of new research laboratories now under construction near Whiting, Indiana.

Research Achievements

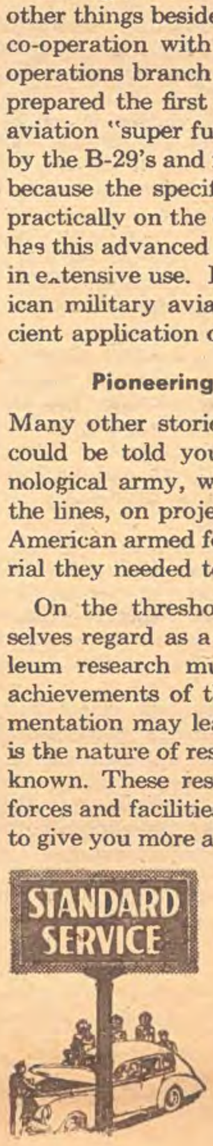
Here in the midwestern part of the United States is a research institution capable of attacking a great variety of problems in petroleum chemistry. Its personnel totals 200 scientists and about twice that many technicians and assistants. Doctors' degrees are more numerous in the laboratories than in college halls. And their number is growing. When the great new laboratories now under construction in Hammond, Indiana, are completed they will house 420 scientists and 800 technicians and helpers.

During the war these technologists did many other things besides the atomic bomb work. In co-operation with their fellow workers in the operations branch of the Whiting refinery they prepared the first large test quantity of a new aviation "super fuel" designed specially for use by the B-29's and fighters. The job was difficult because the specifications had to be balanced practically on the edge of a knife. America now has this advanced new fuel, though it is not yet in extensive use. It is a fuel which puts American military aviation further in front in efficient application of petroleum power.

Pioneering for a Happier Future

Many other stories of the work of these men could be told you. They are a mighty technological army, who worked here, far back of the lines, on projects which helped to give the American armed forces superiority in the material they needed to win.

On the threshold of what scientists themselves regard as a new age, the goals of petroleum research must now be set beyond the achievements of the war years. Where experimentation may lead no one fully knows, for it is the nature of research to pioneer into the unknown. These researchers are extending their forces and facilities to help keep you secure and to give you more and better products. They will follow their great opportunity wherever the stream of development may lead.



STANDARD OIL COMPANY
(*Indiana*)

MODERN ALCHEMY MAKES PRODUCT WORTH MORE THAN GOLD

sort is applied. The fire starts spontaneously. Neutrons set free by cosmic rays or by radioactive impurities in the oven or its fuel initiate the fire.

But there is no flame, no smoke, no fumes. The blocks of metal simply get hot. How hot they become depends on the temperature that the operators want.

The controls for this nuclear fire are less complicated than the drafts and valves of many ordinary heating plants. The controls are long metal rods or strips. They are usually cadmium, a common silvery white metal, or boron steel. Either of these elements absorbs neutrons, and this absorption stops the neutrons from spreading the fire. To slow the atomic heat, the rods are pushed in. These rod controls are operated automatically, like a thermostat, to maintain any chosen temperature. The rods also control the time when an atomic fire starts. In the first ovens, the fires started when the last rod was pulled out the last foot-and-a-half.

The heat is due to the splitting of atoms of uranium 235. About five particles come out of each split. Two of them are the halves of the uranium atom, and the others are neutrons. The friction of these particles as they pass through solid matter or air creates heat. This heat can be calculated. It would be a temperature of trillions of degrees provided all the energy of the speeding particles turned into heat. But some of the energy is converted into motion, imparted to struck particles. Part of the energy is radioactivity. The actual heat becomes millions instead of trillions of degrees.

However there is no danger of atomic ovens flashing instantly into a lot of incandescent vapor. For the extremely high temperatures exist only very close to the atomic split and in minute particles These temperatures drop very rapidly with distance For that reason, atomic fires start with low temperatures the same as stoves burning ordinary fuels

But because the temperatures of the atomic splits are so extremely high, the atomic fuel, when used for producing heat, lasts an almost incredible long time Or to put it in another way, a mere pinch of this fuel will yield the heat equal to that from many pounds or tons of other fuels. While it is burning, this atomic fuel creates new fuel to replace that which has been burned. The replacement may be either partial or complete. How long a pile will continue to give useful heat with one loading depends on the percentage of uranium 235 or plutonium in the original fuel, and other factors not yet fully developed.

The first atomic fires burned normal uranium that is, the metal composed of both 235 and 238 weight atoms. In this normal uranium the 235 is only seven-tenths of one per cent of the total. That percentage is one of the most interesting of all the atomic energy discoveries. Had the 235 amount been only a little less, no atomic fire would be possible in normal uranium. At a far earlier time in the earth's history, there was two or three times more of the 235 in normal uranium. This explosive material has since then disappeared due to slow disintegration Man came along with his great discovery just in time to take advantage of the waning percentage of 235

This fact is no insuperable handicap however For the purposes of using atomic energy, more efficient fires will be built by using uranium 235, and other splitting atoms, that have been refined to the point where the percentage is higher than that in normal uranium Meanwhile, the normal uranium used for the first nuclear fires is absolutely safe from dangers of atomic explosion.

The graphite bricks are used because of a peculiar characteristic of the splitting atoms Neutrons that have lost about all their speed and nearly all their energy are far more efficient at splitting uranium 235 atoms than the 9000-mile-a-second neutrons and the neutrons carrying electrical charges of millions of volts each.

A neutron with very weak voltage, which means very slow speed, is the most efficient projectile for splitting an atom of uranium, or plutonium. The speeds of these slow neutrons are not given, but their energies are as low as one-fortieth of one volt The carbon in graphite is a very good substance for slowing down the neutrons. These atomic particles when emitted are travelling at terrific speeds, and they have to be slowed down to make a fire efficiently. Carbon does not split when hit by the neutrons. The latter merely bump around from carbon atom to carbon atom, like a cue ball. Sometimes the neutron cue ball makes 200 hits on carbon atoms before it gets slow enough to be a highly efficient atom splitter.

Heavy water makes a very good atomic oven, or perhaps nuclear teakettle is a more exact description. The heavy water serves to slow down the neutron speeds until they become efficient in splitting the 235 atoms.

The Allies did not make large heavy water atomic ovens because they lacked sufficient quantities of this material. The Germans had heavy water and used it as the Allies would have liked to do. The Germans also used graphite for making atomic fire ovens.

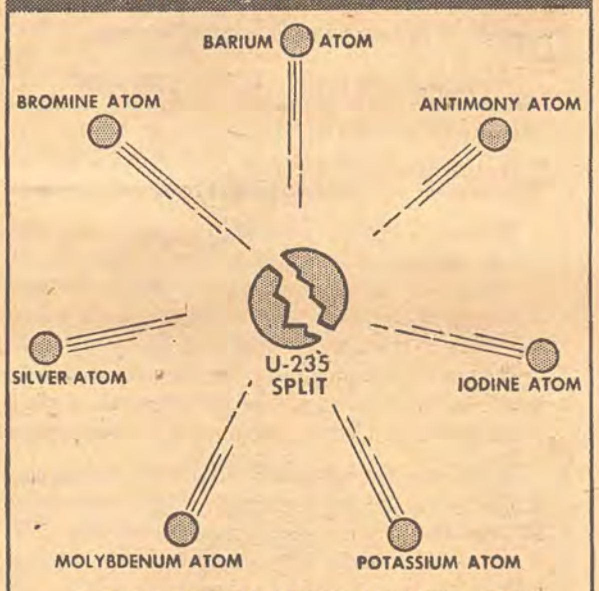
THE THREE-YEAR FIRE

THE building of the first atomic fire in America took nearly three years. This was longer than any other single step. The reason for the delay was the difficulties inherent in making a fire in normal uranium that had so very little of the burning 235 materials. Much of this atomic fire work was done before any attempt had been made to extract the 235 and concentrate it in amounts that would have been much easier to burn.

Using normal uranium, the very first atomic ovens weighed six tons or more. These ovens were not intended to start fires, but only to discover principles. They were used much like taking a log of wood and holding a match to it. There is a slight fire until the match goes out. In place of matches, these early ovens used atomic blow torches, made of a little radium mixed with beryllium. This combination emits a stream of neutrons, and the neutrons in striking uranium showed what could be done.

The Germans, in their search for atomic bombs, went through this same stage of using atomic blow torches of radium and beryllium in small graphite ovens. They had also the advantage over the Allies of heavy water ovens. These comparisons are significant because they mean that had the Germans possessed the manpower they would very likely have produced atomic bombs. As far as their experiments proceeded, they duplicated the road travelled by the Allies. In addition to lack of manpower, the Germans lacked the spirit of free enterprise that drove the project to success in America, and the Nazis also persecuted and expelled some of the scientists who would have been able to help them make bombs.

New Atoms from Old



A TOTAL OF TWO ATOMS OF THESE TYPES IS FORMED WITH EACH URANIUM SPLIT.

TWO complete new atoms of ordinary chemical elements are formed from each split of a uranium or plutonium atom. The new atoms are temporarily radioactive and make up the ashes in an atomic oven. At least 25 such new atoms have been found Only two are formed by each split.

By December, 1942, with the American phase of the war a year old, time was running perilously low for the Allies in their atomic bomb project. Enrico Fermi headed the group experimenting with atomic fires. By that December his associates had built more than two dozen atomic ovens. But there had been no real atomic fires.

Fermi set up his last oven on the floor of a squash court under the west stand of Stagg Field, at the University of Chicago. This pile of graphite bricks was shaped like a doorknob. It weighed many tons. The scientists still did not have enough uranium metal to fill this oven. They supplemented the metal with uranium oxide, a heavy, black salt. Each day a little more was added to the oven. Each day came closer to the load that was expected to take fire. Actually the scientists miscalculated this load. They figured on using more uranium than was needed. But they safeguarded their experiment with long strips of metal thrust into the doorknob oven like hatpins into a hat. The metal strips were neutron-absorbers.

On the morning of December 2, when the absorbing strips were partly withdrawn, the long-awaited fire started.

In Washington, Dr. James B. Conant, president of Harvard University and deputy for the atomic project under Dr. Vannevar Bush, was waiting for word from Chicago. A camouflaged message was sent to Conant, based on the fact that Professor Fermi was a native of Italy. The message read:

"Italian navigator has landed on the new world. He found the world somewhat smaller than he expected."

Conant replied: "Were the natives friendly?"

"Yes," was the enswer.

The "yes" was assurance that no unforeseen difficulties had been found in the fire. The "smaller world" meant that the fire had started with less uranium than anticipated.

Present at this first atomic fire built by man was an observer for a commission upon whose decisions would depend appropriations for about one billion dollars. Because of secrecy restrictions, this commission member was not permitted to tell what he had seen. But by the shining of his eyes, his colleagues knew.

This first nuclear fire made by man, when compared with later steps, was utterly tiny. It would have taken this fire seventy thousand years to produce enough plutonium to make one bomb. Nevertheless, in the end, the fire proved to be the most valuable of all the war-time accomplishments for the progress of peace-time uses of atomic energies.

ALCHEMY AND PLUTONIUM

ALCHEMY and transmutation of the elements came true when the Hanford site atomic ovens were placed in operation. Of all the dreams realized in the atomic project, this one is perhaps the sweetest, safest and the most magical for future uses.

The great ovens were erected to make plutonium, a new kind of metal. Plutonium is the first synthetic or man-made metal. The manufacturing process is pure alchemy. Ordinary uranium, of the atomic weight 238, the non-bomb metal, is transmuted into an entirely new metal. This is plutonium, which has an atomic weight of 239. The plutonium atoms are heavier than anything else known in nature before the war started. They were first made for bombs because they explode like uranium 235.

The original alchemists of the middle ages wanted to transmute baser metals into gold. They were ridiculed. But now the world owes them a vote of thanks. Although they never succeeded, their work started the science of chemistry, with all its practical benefits to man. And the modern chemists who worked on the atomic bomb project were a very large factor in the success of the bomb and of the peace-time progress ahead.

Long before the war, scientists knew the processes of transmutation. But little attention was paid to these modern alchemists. They were unable to make sufficient amounts of transmuted elements to be visible even under a microscope. Plutonium was the first visible and relatively large-scale achievement in alchemy. The value exceeds that of all the gold in the world. This is true not because plutonium can be used to make bombs, but because it is one of the great resources for atomic power.

When it was decided to transmute uranium into plutonium, the task of initiating the scientific work fell to Dr. Arthur H. Compton, Nobel prize winner in physics, who was then head of the metallurgical section of the atomic bomb work at the University of Chicago. He ran into difficulties. He went first to one of the great industrial corporations and asked that company to undertake the alchemy job. The executives said they had no experience in transmutation, and no personnel trained for it. Then Dr. Compton went to one of his friends, the president of a New England university. He asked whether that university would undertake the sponsorship.

"I don't believe," replied the President, "that my trustees would touch it with a ten-foot pole."

At that stage, for a university to stake its reputation on a plutonium project was somewhat like agreeing to back the world's potentially greatest boondoggle. The uncertainties were tremendous. Dr. Compton returned to Chicago. President Hutchins of the University was away. Time was pressing. Dr. Compton talked to one of the members of the University of Chicago board. He described the project and the risks. Then he remarked:

"———— University won't undertake it."

"Oh," mused the Chicago board member, "so ———— University won't."

Thereupon he called another member and they talked it over. The Chicagoans got together for a conference. Dr. Compton told them: "This is a gamble, but I think it is worth trying."

The Chicagoans decided to undertake the job. This may not have been the greatest gamble ever undertaken by any university. But it was the first time that a great university undertook the sponsorship of a new industry on a big scale. The university furnished members of its staff for the scientific planning.

The first alchemy plant was erected at Oak Ridge, Tenn., hidden in a valley. Although this structure rated only as a pilot plant, it was bigger than many a large industry. The DuPont Company set up and engineered the plant. Later Monsanto Chemical Company took over the Oak Ridge operation. The DuPont Company went to Washington, there setting up, engineering and operating the great plutonium ovens. Time was so urgent that completion of the Oak Ridge pilot plant was not awaited.

Dr. Compton's duties took him both to Oak Ridge and to the Hanford plant in Washington. Military secrecy required him to have two code names, one for each location. He was Mr. Comus in one area, Mr. Holly in the other. Sometimes the duality caused confusion. Once when flying between Oak Ridge and the west coast he got off the plane about midway for a bite of food. When he boarded the plane again, the stewardess, with a pencil poised over her passenger check list, said:

"Name, please?"

Dr. Compton was embarrassed. His name was on a slip of paper in his pocket, and he did not recall which one he had given when the flight started.

MAGIC IN METALS

IN the Hanford ovens, when an atom of uranium 235 splits, some of its emitted neutrons keep the fire going by breaking other 235 atoms. Most of the remaining neutrons hit atoms of the weight 238. In this second type of hit, the uranium nucleus does not split, but absorbs the neutron. A neutron weighs almost precisely one atomic unit. Thus when one neutron is added to uranium 238, the weight is raised to 239. This change in weight is transmutation. Alchemy is as simple as that. The difficulties in alchemy are not in the principle. They are in the expense of the very high energies required, and in the fact that transmutation takes place one atom at a time. The yield is low.

In the Hanford ovens, this new atom of the weight 239 emits some rays and starts rearranging the particles in its core. In a little more than two minutes on the average, this atom that was originally uranium is transmuted into an atom of a different metal, neptunium. This form of neptunium is not stable. It goes on emitting rays and finally one electron, and in the average time of two days becomes plutonium.

This new plutonium metal has a half-life of 24,000 years. This period of time means that in 24,000 years half of any given quantity of plutonium will emit enough rays to change itself into a different element. The change made by plutonium is back into uranium, but not the 238 kind. Plutonium becomes uranium 235. And here, using atomic fires, man has something that at first glance resembles perpetual motion. For the uranium 235 makes the plutonium that afterward reverts to uranium 235, which in turn can make more plutonium. However this is exceedingly slow motion, and of no practical use.

The new plutonium atoms remain in the uranium metal. As long as they are left there, they will split like the uranium 235, and these splits help to continue the atomic fire and also to make more plutonium. But the exploded atoms of either uranium or plutonium are of no further use for fire. Both, when they split, become two atoms of about half their original weights. These smaller atoms are not the kind that split.

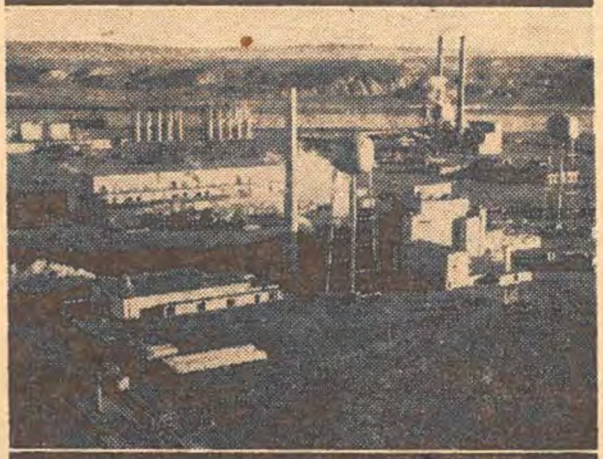
Plutonium makes good bombs. Official reports have called plutonium super-bombs. The main military reason for making plutonium was the fact that it was thought easier to separate this metal from normal uranium than to extract the uranium 235. When this decision was made, there was no certainty that the 235 variety would be extracted in time for the war

THE CHEMIST TAKES OVER

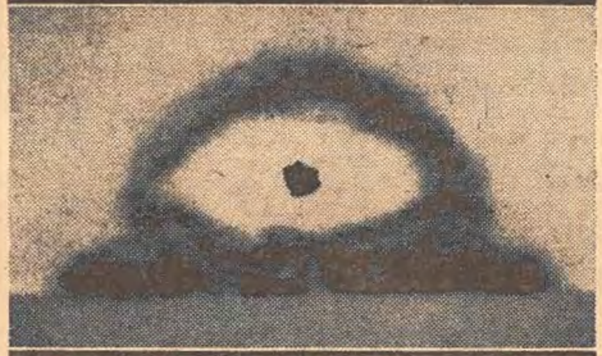
PLUTONIUM separation is by chemical processes that have been used in industry for many years, in contrast to uranium 235 extraction which was entirely new. Nevertheless how this chemical separation is done is in its detail the third secret of the atomic bomb. To effect the separation, the blocks of uranium are pushed out of the ovens and make an underwater journey of several miles to separation plants. Here is the reason for having the uranium in aluminum cans. The aluminum protects the metal from the water, which would otherwise partly dissolve it. The separation plants are three great man-made canyons. In the separation there are about thirty major chemical steps, and in addition several hundred lesser processes.

Landmarks of the Bomb

THIS PLANT WAS BUILT IN TENNESSEE . . .



AND THIS IN WASHINGTON TO ACHIEVE



THE FIRST ATOMIC BOMB IN NEW MEXICO . . .

WHICH LEFT THE GROUND LIKE THIS . . .

AND LED TO THIS AT HIROSHIMA IN JAPAN.

Great cranes are used over these canyons. The cranes are run by remote control, by operators who look through a periscope thrust out above the shielding walls behind which the men hide from the canyon's atomic rays.

The yield of plutonium for each ton of uranium cooked in the ovens is a few grams, equivalent to the weight of a few nickel coins. However, the uranium can be cooked again and again, each time yielding its quota of plutonium. Nothwithstanding the low yield, and the size and expense of separation methods, the ease with which plutonium can be split with slow neutrons, and the 200,000,000 electron-volts of energy from each split, give plutonium good chances to compete, along with uranium 235, with coal, oil and gas.

Plutonium started as an idea, in mathematical symbols on paper. It was an unknown metal that should, in these calculations, make good bombs. Many scientists did the figuring. Among these groups were Dr. E. O. Lawrence and associates of the University of California and some of the British.

The Californians, with the aid of their cyclotrons, produced sub-microscopic amounts of plutonium. This was in 1940. But this first transmutation product was not the same kind of plutonium that makes bombs and that is produced in the Hanford atomic fires. This early plutonium has a half-life of only 50 years. It was useful in making some calculations of the chemistry of the explosive plutonium that came along later. It was discovered by G. F. Seaborg, E. M. McMillan, A C Wahl J W Kennedy and P. H. Abelson.

Two years later the first atomic bomb plutonium was made at the University of Chicago by B. B. Cunningham and L. B. Werner. There for the first time ever a synthetic metal, plutonium, was made in sufficient quantity to be visible. The amount was only a few millionths of a gram, and a gram is only one twenty-eighth of an ounce. So tiny was this bit of plutonium that when the scientists called General Groves to view their achievement, he said "I don't see anything." His remark was justified. Nobody could be sure of seeing this bit of plutonium unless the guide put a finger almost on it.

Nevertheless with this, and some other equally tiny samples, the chemists did in a short time a job that ordinarily would take five years or more. The job was to learn the then unknown chemistry of plutonium. To succeed in this, the chemists extended the recent science of micro-chemistry that makes analyses with tools ranging in size from a grain of sand to a penny. They made micro-chemistry into atomic-chemistry, which went literally into the invisible. To weigh the bits of plutonium a new balance was invented. This scale was made of quartz fibers and some of its parts were so fine that they were visible only under microscopes.

One of the new transmuted metals produced in the Hanford ovens is a stable element that will last millions of years. It is neptunium, but not the same form of neptunium that changes into plutonium. The latter form lasts only about two days. Several other new metals, none of them known to exist in nature can also be made by use of the nuclear fires. The uses of all these new metals except two are unknown. The exceptions are plutonium, and an entirely new form of uranium that can be made from the metal thorium. The new uranium is good for atomic power purposes.

But the new synthetic metals, whether their uses are known or not, open a field of alchemy that exceeds the wildest dreams of the original alchemists. More than 500 of these transmuted elements had been made before the war by cyclotrons and other high energy apparatus. The amounts in all cases were too small to be visible. Even so some of them were useful in medicine and biology.

The experiments on such minute quantities charted the way to the future. That future now becomes reality, made so by nuclear fires that can be used on an industrial scale for transmutation and alchemy

INTO THE FUTURE

THE first practical industrial use for atomic energy was to see into the earth to look for oil. The request for atomic materials for this purpose was made a few weeks after the war ended in the Pacific.

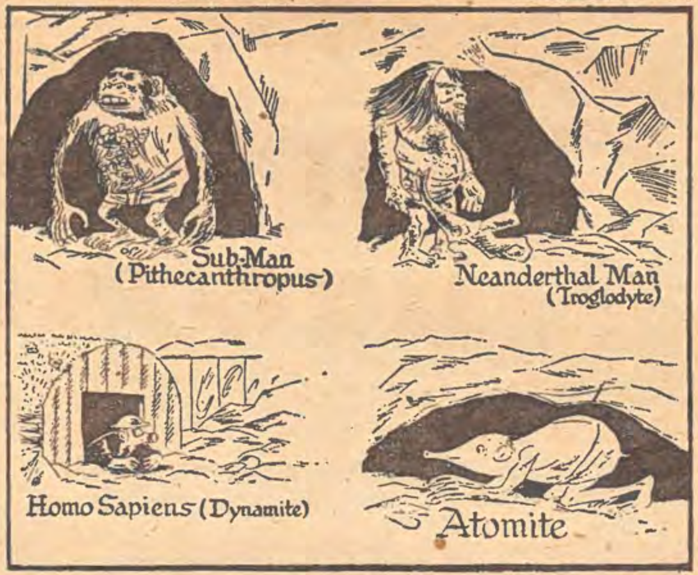
This was about the last prospect that might have

Splitting the Atom Has Produced Some of Mankind's Gravest Fears . . .

THE THREAT OF THE FUTURE

Barrow, AP Newsfeatures

DARK ANGEL OF PEACE



Vicky, London Chronicle

EVOLUTION

ATOMIC BOMB GUARANTEED TO DESTROY EVERYTHING
AT LAST!
MARS

Justus, Minneapolis Star-Journal

HE MUST NEVER RISE AGAIN

been anticipated by a good prophet. It typifies the outstanding fact about atomic energy, namely that most of its peace-time uses are unpredictable.

The oil prospecting request is founded on no mere theory. It is based on a practice that was begun about the time the United States entered the war. When oil wells are about to run dry, a bit of radium mixed with the salts of beryllium is lowered down the well slowly. This combination emits neutrons. These particles penetrate the steel casing and concrete backing as easily as going through butter. They drive into the earth all around the shaft. There they hit cores of atoms, and transmute them. The transmuted atoms emit X-rays, some of which penetrate back into the well hole. An X-ray meter, lowered down the shaft, reads these radiations. By the volume or pattern of rays, experts can tell fairly well the location of any pool of oil that may have been missed in the original drilling. By this method, numerous by-passed oil pools were discovered during the war. Some of them produced from 200 to 1000 barrels a day.

Radium is very expensive. The atomic ovens produce radioactive materials that are comparatively cheap. The ovens make transmuted elements that may extend the oil prospecting to places where radium fails.

The first great energy application of uranium and plutonium is likely to be for large power plants. The atomic energies will give heat the same as coal, oil and gas. The heat will be used precisely like that of other fuels. It will make steam, or heat gas to drive a turbine, or use either steam or turbine to drive a generator to make electricity, or heat mercury as a substitute for steam.

The hot metal blocks of uranium or plutonium will substitute for furnaces. They can heat a liquid metal that in turn will heat boiler water. They may heat the water directly. Either method can be used to heat turbine gases. If heavy water is employed in place of graphite ovens, the water itself may be raised to steam super-heats, and then serve as the stove to heat water or gas. All these methods require few changes in design of existing power plants.

The splitting atoms do not give off electricity, despite the fact that their energies are measured in electron-volts. That electrical unit is used merely as a convenient yard stick. Nevertheless there is hope among scientists of discovering some way to take electricity directly from splitting atoms. Many of the splitting particles carry electrical charges. That fact is the basis for such speculations.

In the three atomic ovens at Hanford, Washington, that were built specially to make plutonium and not for power, the heat alone approaches the total power expected from Grand Coulee dam. If all this atomic heat were converted into electricity, there would be nearly as many kilowatts as are expected from the great dam. This Hanford heat is low-grade. That means that no one place in the ovens is excessively hot.

At Hanford the heat is got rid of by piping Columbia river water through the ovens. Never before was there such piping as this. The pipes are each only a few hundredths of an inch in diameter. But through them flows daily a volume of water that would equal the daily consumption of New York City. There is so much heat that even after the water has been cooled before returning it to the Columbia, the great river is warmed. But the warming of the river is only about one-tenth of a degree. For practical purposes the Columbia is not warmed at all. But if ever warming a whole river should become a worth-while job, atomic ovens might do it.

"TROUBLE-LESS" POWER PLANTS

THE heat in the Washington atomic piles comes entirely from normal uranium, which is the ordinary metal made from any uranium mineral. This normal uranium is burned without any attempt to refine or enrich its content of uranium 235. Far more intense and concentrated temperatures would be available with enriched uranium.

These blocks of metal that get hot without flame, smoke, fumes or dirt, and with no noise, have other advantages over fire. No matter how fast the heat is drawn away from them, the blocks do not cool. Their temperatures remain uniform, at the degree set by the automatic controls. Describing these ovens, an enthusiastic scientist said to his colleagues of the National Academy of Sciences and the American Philosophical Society:

"I wish I could show you an atomic power plant. It is the sweetest operating machinery, running with the least trouble, of any power plant that I know."

At the Clinton Engineer Works at Oak Ridge an atomic power plant ran for eight hours without need for an operator to make any adjustments. At the Ardennes laboratory of the University of Chicago, one of the very first power plants ran three years without serious difficulties.

An inherent advantage of the metal blocks is that a relatively small-size heater may give a lot of power. Another advantage is less corrosion of the sort due to excessive heating. The metal blocks are readily controlled against heat fluctuations.

With ordinary fuel, the amount of heat is limited by how fast the fuel burns. That is not true of atomic fuel. In an atomic oven the limit of the heat is the melting point of the materials forming the oven. A present disadvantage of uranium is the melting point of that metal. This is about 2100 Fahrenheit. Melted uranium however can theoretically be made to continue giving heat, and scientists expect to learn how. When that is done, atomic fires can be run up to thousands of degrees as soon as metallurgists discover alloys to make ovens that will not melt.

The wartime fission fires used many tons of uranium for a single oven. The tonnage will be sharply reduced when enriched uranium 235 or plutonium or thorium are used. For power purposes 100 pounds of plutonium is equal to 100 tons of normal uranium.

When the cost of fuel alone is considered, uranium is more efficient than coal, oil or gas. Compare, for example, the 200,000,000 electron-volts coming from one splitting atom, with the four electron-volts that come from two carbon atoms separating in ordinary fire, or about 35 electron-volts given off when an entire molecule of T.N.T. is consumed. It should be noted that fuel costs, in efficient power plants, are not a high percentage of total expense.

An interesting angle of atomic fuel is its peculiar ashes. They are invisible. This atomic ash is the split atoms of uranium or plutonium, two of which form at every split. Both remain inside the metal. Their volume is slight.

The atomic ash that would form in one day in a ton of uranium at Hanford might be no larger than a few thin dimes. But some of these new atoms have the ability to absorb neutrons. That means that the peculiar ash would ultimately extinquish the fire, since the margin of neutrons to keep the fire going is not large. Ultimately the atomic ashes have to be removed, a process more expensive than cleaning a furnace. But once the atomic fuel has been purified it can be burned again. That can't be done with ordinary fuel. Furthermore, with enriched uranium or plutonium, the ash problem is easier. Finally, these atomic ashes are valuable by-products, being useful minerals of two dozen varieties, and having useful radioactive properties.

The great handicap to atomic power is the rays from the nuclear fires. These are so intense and dangerous that about fifty tons of steel, or its equivalent, would be needed to shield a hundred horsepower atomic fire. That is not more power than the rating of many automobiles. No shields of less weight, or bulk, are likely to be possible. The laws of nature are against discovery of better shields. For the penetrating power of these rays has been tested for virtually every element in nature. One ray or another pierces every type of barrier. The atomic fires emit all kinds of rays simultaneously.

The world did not realize that man has had atomic energy at his disposal, in small amounts, ever since Becquerel discovered the slight radioactivity of uranium, and the Curies discovered radium. The new atomic energies are either the same as the pioneer rays or are more dangerous, because they are more intense. In addition the atomic fission releases rays that neither Becquerel nor the Curies knew.

The rays make it necessary to confine atomic power plants to projects where safe shielding is feasible. There are many of these. Shielding is feasible for plants making light, heat and power for cities. Atomic plants would do well in areas where no other power is available cheaply. This would apply especially to dry areas with no water power, and remote areas where hauling in of fuel is expensive. A few hundred pounds of atomic fuel could replace millions of tons of coal or many trainloads of oil.

The graphite brick used for the first American atomic ovens is neither the only nor the best material to make the moderator for a power plant. Graphite was used because it could be had more quickly. Heavy water has advantages. The Allies were experimenting with heavy water during the war. A drawback to heavy water has been the great expense of making it. There are other chemical elements that may be used advantageously. The prospects for power improvements are unlimited.

Because water is one of the good shields against neutrons, most dangerous of all the atomic rays, use of atomic plants to drive ships is a favorite early objective. One plan is for submarines. The U-boats might travel at high speeds under water, submerge to depths that may be safe even from atomic bombs, and remain under indefinitely. These speculations are based on having a great excess of power that would do everything including making available large oxygen storage space.

LAKES IN THE DESERT?

AMONG the dreams that appear to have possibilities, the British have offered some based on use of atomic materials for blasting. Even with ordinary explosives, the greatest uses have been as "blasting agents," a term preferred by manufacturers for

(Continued on Page 22)

Television... all set for the ATOMIC AGE

If you have looked upon high-fidelity, low-cost television as a pleasure that must be placed in the far distant future, then Raytheon has a happy surprise for you.

It's coming this year . . . television that will make your own easy chair a grandstand seat from which to view events of this fast-moving atomic age . . . television that will be remarkably low in price. In these new sets by Raytheon, you will benefit by the results of broad and long wartime experience, greatly accelerated peacetime research, and unexcelled engineering.

Raytheon is leading the way in bringing television at its finest within reach of every American home.

RAYTHEON

Now released for production, this television set by Raytheon, combining faithful reproduction of both sight and sound, will be compact enough to place on a table yet will show a picture for the whole family to see.

Belmont Radio Corporation

A DIVISION OF RAYTHEON MANUFACTURING COMPANY
5921 WEST DICKENS AVENUE • CHICAGO 39, ILLINOIS

avoiding the unpopularity attached to munitions-making. Without these agents many automobile roads and magnificent buildings would not have been constructed nearly so soon. These blasting agents did much to take the world out of the pyramid-building stage.

Tha British vision forecasts blasts that will transform landscapes, dig great holes and trenches for lakes and canals. Lakes may become possible in the midst of deserts. Some of the world's worst places may be converted into oases and fertile countries. There may be immense and constant sources of heat to make Arctic regions comfortable. At this point in the forecast the British prognosticator apparently made a slip. He said that the North Pole might very well make a resort. The South Pole might make a resort, but the North Pole is covered by deep ocean water and floating ice, and drying up oceans is not an atomic energy project.

Nevertheless, the conversion of ocean or other salt water into fresh water for irrigation is by no means beyond the scope of the foreseeable atomic age. Conversion of ocean water would be facilitated by cheap power. Many long-time dreams of engineers and scientists can be made to come true whenever power becomes sufficiently plentiful and inexpensive. These include lighting the night sky with radio waves to give a fluorescent glow that will substitute for street lighting. Others are harnessing the tides; many projects of irrigation; raising some agricultural crops outdoors, out of season, with the aid of artificial heat; and many ways of making hot weather more comfortable both by cooling and by the more difficult task of controlling humidity.

Pilotless rocket or jet propulsion ships, radio controlled, may be the first atomic-powered vehicles. As long as they have no human beings aboard, these ships require no shielding from their own atomic rays. Shielding set up about the take-off sites would be sufficient.

The main engineering obstacle to space ships of the sort that might fly to the moon has been the weight of fuel required. With atomic energy metals this weight problem can be solved. Atomic fuels, such as uranium 235, will be small and concentrated. But before atomic-powered air ships are possible, it will be necessary to solve the problems of applying atomic energy in small amounts. Much study is needed to learn how the few pounds of metal that can blow up a city may be scaled down to emit just a little of its force at a time.

One of the serious obstacles to space ships is expense. This may be relieved to some extent by experiments likely to be made for military defense purposes. Rockets that could be fired into space if anybody wished are likely to become possible early in the atomic age. This is due to the compelling necessity of learning quickly how to shoot atomic rockets that will at least span oceans. Any nation that develops atomic-powered rockets, while its neighbors have none, is well on the way to having the rest of the world at its mercy. In fact the rocket, with atomic power in its tail and an atomic bomb in its head, appears to be the supreme weapon of all time.

Pilotless radio-controlled ships, flying to altitudes of 100 miles or more, could obtain scientific information that will be needed before human beings can venture outside the stratosphere. One question is the effect of meteors or "shooting stars" on space ships. Astronomers estimate that probably twenty million meteors fall into the earth's atmosphere daily. It is likely that the number is far larger. These meteors are mostly small, a great many of them about the size of grains of sand. But these grains sometimes have velocities of 40 miles a second, and much faster meteors have been clocked. Even the small grains at such speeds would be expected to penetrate any kind of space ship armor that can be devised until stronger alloys are made.

How high above the earth's surface the thinning atmosphere and the strong electrical forces up there influence the weather can be learned by pilotless atomic ships. The air currents at 50 miles altitude, and higher, have been recorded by good evidence as running close to 200 miles an hour.

One fact that appears to tower over most of the others at the start of the atomic era is that coal, oil, gas and other natural fuels will not be abandoned. They will continue to be useful, even though they may someday be only supplementary fuels. The history of scientific progress runs that way. Old resources are not abandoned. They find new uses, and more uses, in the new era than in the old.

NEW SOURCES OF URANIUM

THE atomic age began with some limitations in the resources of uranium that were more apparent than real. In the known pre-war resources, the total uranium 235 available was apparently not more than enough to produce the electrical power of the United States for two years. This moreover was at the prewar rate of electrical power production. By using atomic ovens with U-235 to make plutonium, this American electric power figure might be multiplied by 50 times or more. But it appears that far more uranium will be available fairly soon than was dreamed of before the war. This extra supply is not alone from the possibility of discovering new deposits.

The new sources will be in the so-called low grade uranium minerals. There are at least 115 different known minerals that contain uranium in one or more of 500 different compounds. Of all these, before the war, only two, pitchblende and carnotite, were considered commercially useful sources. The 235 uranium is distributed all through the low grade minerals the same as in the pitchblende and carnotite. And this U-235 can be burned without the necessity of first reducing the minerals to the metallic form of uranium that was used for bombs and for the first atomic ovens in Washington.

In thorium there is a possibility of atomic power resources that will exceed the making of plutonium. This is in the transmutation of thorium into uranium 233. The latter is a form of the metal not known to exist in natural uranium. This new form of uranium has one apparent advantage over both uranium and plutonium for power purposes. It may not react fast enough to make atomic bombs. This slower reaction time may well be used to produce power more efficiently.

There are further possibilities in the non-explosive uranium 238. Although this common form of uranium does not split to any extent in the chain reactions developed during the war, it nevertheless possesses the peculiar splitting ability of the other forms of uranium. This U-238 actually splits spontaneously. These splits are comparatively rare. But they may furnish a clue to a chain reaction that was unknown in the early developments.

By the time the war ended, a great amount of information already had been collected about the peaceful applications of atomic energy. Several different kinds of atomic power fires were known and more than one had been experimented with. They were merely stepping stones. There were so many of these, however, that there was no question of ultimate success.

THE 'NEW' RAYS

THE radium-like chemical elements created by the atomic ovens, had they not been overshadowed by the atomic bomb, well might have been rated as the greatest scientific discovery of the century. These ovens are the sources for making rays that will do everything radium accomplishes, and much more.

For the first time, with the aid of the nuclear fires, man can cause any and all kinds of matter, including his own body, to emit radioactive rays. For the first time he can do this at reasonable costs.

None of these rays is new. All have been produced in laboratories, or foreseen as possibilities in laboratory experiments. But they were seldom useful, because they were too weak and too costly.

There are six kinds of these rays. Two of them are immaterial, like light. The other four are streams of particles that are so tiny they pierce solid matter easily. The immaterial rays are X-rays and gamma rays. The distinction between the two is artificial. X-rays are made by power tubes. Gamma rays come from radium and other radioactive, natural chemical elements. In the early days, the gamma rays always penetrated farther than the X-rays, hence the two names were used. Today, with new electrical apparatus, X-rays can be made that are more penetrating than any gamma rays.

The particle radiations are beta, alpha particle, proton and deuteron. Beta rays are streams of electrons or of positrons. Positrons are positively charged particles of the same weight as electrons. The latter carry negative electrical charges. Alpha particles are the heaviest of all the rays. They are the cores of atoms of helium, having each an atomic weight of four. Protons are heavy, positively charged particles, with an atomic weight of one. Neutrons are about the same in weight, but have no electrical charges. Deuterons are the cores of heavy hydrogen, and have an atomic weight of two. Proton and deuteron rays are not common in natural radiations. All the other four appear in large amounts in nuclear fires and their by products.

The source of the new rays is the splitting of the metallic atoms, whether of uranium, plutonium or of the thorium-uranium kind. The splits themselves emit rays far more intense and powerful than anything previously known.

These rays directly from the nuclear fires also

. . . . . And Has Given Rise to Some of His Brightest Hopes

Alexander, Philadelphia Bulletin

RESHAPING THE WORLD

Hungerford, Pittsburgh Post-Gazette

GOD'S ATOMIC POWER

Fitzpatrick, St. Louis Post-Dispatch

A NEW ERA IN MAN'S UNDERSTANDING

ATOM MAY FIND ITS BIGGEST USE IN PEACETIME POWER

render any kind of matter that they strike temporarily radioactive. It is these temporary rays that promise great advances in medicine. biology and industry.

The atomic piles can make the equivalent of tons of radium. The entire world supply of radium is only two pounds. Still smaller has been the supply of radium-like elements that now become available. The nuclear ovens produce. as regular byproducts in the uranium metal, about thirty temporarily radioactive chemical elements, each one about half the weight of uranium. A score of these are made in fairly large quantities. The temporary rays are emitted over periods ranging from a few minutes to years.

In addition to all these, virtually any ordinary chemical element, placed inside the nuclear ovens, will become temporarily radioactive. Some will emit one type of rays. others a different kind.

BLOCKING THE RAY KILLERS

THE intensity of the new sources of rays is appalling. If the Hanford ovens were not shielded by tons of material, any human being approaching them closely when they were in operation would be instantly killed. There never have been rays of such intensity on earth. The shielding of the ovens even has to be air-tight. For the air itself inside the shields becomes dangerously radioactive, and leaks would be unsafe to those outside.

When the canyons were built at Hanford to separate plutonium from uranium, the question arose as to whether the canyons needed roofs to prevent radioactive rays from shining up against the sky and reflecting back to earth. The canyon rays are emitted mostly by the thirty by-product elements. The canyons were built with roofs. There was no sky shine. Whether there might be a dangerous reflection from the sky is probably an academic question But it gives an idea of the amazing power of the nuclear rays and of the pains taken to shield human beings.

In an experiment on mice, a single exposure to the beta rays of some pile elements caused skin cancer. Beta rays are streams of electrons or positrons. It was known previously that these rays could cause skin cancer But single-shot skin cancer was new.

When chemists were weighing a quantity of the new metal plutonium so tiny that part of the scales was invisible to the eye, the study was done under remote control. The rays from even the tiny bits of elements on the scales were so powerful that shielding was required.

When uranium and plutonium are fully purified. their rays are not dangerous to human beings, unless they get into the blood. These rays are alpha particles, which are heavy, and do not travel far in air. Plutonium appears to emit the alpha particles faster than uranium. When taken into the blood these particles get into the bones. They are the same sort of particles that caused the deaths of the women in New Jersey who had the habit of moistening with their tongues the tips of brushes to put radium paint on watch faces.

When the atomic energy work began, uranium was believed to be one of the most poisonous elements. Great was the astonishment when mice, on a diet containing uranium oxide. got fat and healthy. Investigation revealed that uranium taken by mouth in small quantities passes through the digestive system without being absorbed into the body But uranium in a body cut is highly dangerous

The first job with the rays was to learn safety measures. Since all forms of matter may become temporarily radioactive when too close to the ovens. there were daily checks for signs of rays of various sorts coming from desks, pens, pencils, clothing, hair and skin of scientific and technological workers. When some workers left their jobs, ray counters tested the front of their clothing, and a couple of steps farther, another counter figuratively felt their backs. Some stepped on a ray meter built into the floor to detect rays from shoes. The air was checked by a counter named "Sneezy." There were also blood tests. Before the war ended, the safety limits were well charted, and the control of the rays sufficient so that science and industry could go ahead with their uses

RAYS ON THE ASSEMBLY LINE

THE industrial possibilities of using rays are numerous. Some of the intense radiations alter the properties of solid materials. One change is in elasticity, another in electrical conductivity. But it is not true that these rays disintegrate solids. Except for the disintegration by heat and pressure, the true disintegrator ray has yet to be discovered. The alterations in solids caused by the rays appear only after long exposure. These effects are also slight.

Nevertheless the changes in structure offer possibilities for industry. It may be possible to improve some materials for special purposes. X-rays already have been used to alter the colors of gem stones.

One of the astonishing things about alloys and plastics is the exceedingly small amount of some chemicals that cause great changes in properties. One thousandth of one per cent is sometimes enough. The reasons seldom have been completely understood. The new rays will cast light on these puzzles. This will be done by exposing the alloying element, or a small fraction of it, to the rays of the atomic ovens. The exposure causes temporary radioactivity in the alloying element. Then, by the rays that the compound emits, every step taken by the added fraction can be traced. This can be done with amounts too small to be seen in microscopes.

There are puzzles about the flow of liquids and gases, whose solutions would be useful for industry. This sort of flow can be followed by use of radioactive tracers.

The atomic ovens do not manufacture radium. But they can make a substitute much like radium, and as useful for many purposes. The substitute is antimony, a hard, brittle, tin-white metal. Placed in the plutonium-making ovens, antimony would become radioactive. In this way the equivalent of many times the radium stocks of the United States can be made in less than one year. Antimony can be used the same as high voltage X-rays to look through metals and see flaws

RAYS VS. CANCER

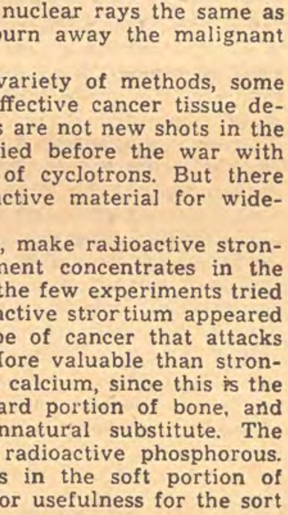
BIOLOGY and medicine, and cancer especially, are the first major patrons of the new ray sources. There are many angles in the proposed cancer attack. One is to use nuclear rays the same as X-rays and radium—to burn away the malignant growths.

The new rays offer a variety of methods, some of which may do more effective cancer tissue destruction. These variations are not new shots in the dark. They have been tried before the war with the radioactive products of cyclotrons. But there was never enough radioactive material for widespread experiments.

Cyclotrons, for example, make radioactive strontium. This chemical element concentrates in the hard portion of bones. In the few experiments tried before the war, the radioactive strortium appeared to concentrate on the type of cancer that attacks the hard part of bones. More valuable than strontium would be radioactive calcium, since this is the natural element in the hard portion of bone, and strontium is only an unnatural substitute. The cyclotrons also produced radioactive phosphorous. This element concentrates in the soft portion of bones, and so has hoped-for usefulness for the sort of cancer than grows in bone marrow.

Also before the atomic age, cyclotrons made radioactive iodine. This form of iodine may be made by the atomic ovens. This iodine did the equivalent of clean surgery, without knife or blood, on toxic goiter in experiments at the University of California school of medicine. The radioactive iodine was simply taken in a drink of water. Nearly one hundred percent of the iodine concentrated in the thyroid gland, seat of the goiter.

The Atom Also Brought . . .



THE atomic bomb put a shiny new adjective into America's lexicon. Since Hiroshima, the words atom and atomic have been worked and reworked and then worked some more.

Things no longer are colossal — they're atomic. They are as world-shaking as the atomic bomb, and anyone courting danger is "fooling with the atom."

The first atomic bomb was an inspiration to the nation's gagsters and advertising geniuses. There soon was an atomic cocktail, an atomic breakfast food, an anatomic blonde and also an atomic magazine.

Within six months, 22 atom-derived company names were listed in the Manhattan telephone book alone. They dealt with everything from chiropody supplies to pleating and stitching. There were atomic lighters, atomic food products, atomic handbags and clothes.

This same iodine was not found, before the war, useful for treating cancer, because it failed to concentrate in any malignant growth. But the iodine discovery is one of the brilliant advances in medicine It is the beginning of a new field of treatment. For this field the atomic ovens could supply most of the materials.

There is another broad attack on cancer. This is to attach radioactive elements to chemical compounds injected directly into a malignant growth. This has been hampered by difficulties in finding suitable radioactive compounds. Now virtually all compounds can be made radioactive, with the promise of enough intensity in the rays for cancer treatment.

The variations possible in this form of experiment seem endless. One of them, tried before the war, is to inject compounds of beryllium into a malignant growth. When X-rays are turned onto this compound in the cancer, the beryllium emits neutrons. The neutrons are one of the rays with high destructive power for living tissues, cancer included. They are too dangerous to be allowed to continue for a long time. But in this experiment, the neutrons appear only as long as the X-rays are on. They stop when the X-rays are turned off.

A most promising type of investigation is the use of radioactive tracer compounds to study the metabolism of cancers. These malignant cells use sugar in a different way than normal cells. They use oxygen differently. And there are other differences. These differences, it is hoped, will some day reveal how malignant cells are able to grow so much more rapidly than normal. If that is discovered, it may prove to be the long sought key to the cause of cancer. Certainly the irradidated tracers will permit many experiments to learn how the metabolism of malignancy is different.

The radioactive tracers used in this way do not destroy or harm tissues. For tracing, very small quantities of the ray-making chemicals are added to drugs, food or other chemicals taken into the body. Because of their intense rays, these tracers can be followed, even when they form only one millionth of the tissues under investigation.

Tracers will aid in making drugs with specific effects on cancer. There have been numerous drugs of this sort. A few of them have temporarily stopped the growth of cancers; sometimes even caused temporary disappearance. But the malignant growths returned, and were fatal. What caused the temporary improvement is still unknown. Radioactive tracers will help in studying this puzzle.

WHERE DO THE DRINKS GO?

OF broader importance to human beings is the tracer work to be done on living tissues in normal health and in diseases of all kinds. This tracer technique, too, was well outlined before the war, but sufficient materials were lacking.

The common elements in living tissues are carbon, hydrogen, nitrogen, oxygen and often sulphur. Carbon is so universal in tissues that it has been said to form the molecules of life. These common elements, exposed to the rays in atomic ovens. become temporarily radioactive. Actually they may not all become radioactive, but each element has more than one weight, called isotopes. One of the forms usually becomes radioactive.

An easy example of the action of tracers would be a drink of whiskey, spiked with a strongly radioactive chemical. This might clear up the debate as to why a couple of drinks cause signs of intoxication in one person, while another can take many without showing effects. There are popular theories, such as that the drinker who can tolerate a lot gets rid of some of the alcohol by changing it into water and carbon dioxide. However the physiologists have not had satisfactory proof. They have suspected that a shot of alcohol gets distributed differently in. the body of the fellow who can drink a lot with little apparent effect.

If a swallow of the spiked whiskey is taken, a ray counter will trace the drink by the noise it makes. This noise is a rattle, sometimes as fast as a machine gun. When the liquor gets into the stomach the rattle will be concentrated there. It can be heard by holding the counter close to the midsection and using amplification to step up the clicking sound.

Later, as the alcohol goes into the blood the noisy drink can be picked up all over. Still later comes the period when much of the alcohol concentrates in the brain. This is the time when the drinker feels the effects. During that stage the rattle should come most strongly from the drinker's head. If the rattle should be just as loud from the head of a teetotaler, who made a mistake and got a good-sized drink, as from a fellow who can drink a pint with impunity, that might be evidence that the grey matter in the brain possesses the secret of tolerance to alcohol. But if the heavy drinker's head does not rattle as much as the teetotaler's, then the alcoholic noise can be sought in other parts of the body The location may explain tolerance.

THE ADVANCING MEDICAL FRONT

THE great radioactive tracer studies concern nutrition, metabolism, growth, the action of many medical remedies and the mystery of growing old. Nutritionists would like to know precisely where different chemical elements in a meal go, how quickly they get there, and how long they stay. More difficult to learn, but more important, is how these elements of nutrition split up after they reach their destinations in the body Tracers will give some of the answers.

Some of the elements taken in food act as living catalysts, enabling the body to manufacture some of its own needs. Vitamins and hormones are among the catalysts of living tissues. There is in addition a great class of catalysts known as enzymes. Some enzymes are just as important as vitamins and hormones But how these catalysts, of any sort, do their jobs is not yet clear. It is known that when the catalysts get out of balance a person's health begins to fail. But what makes this unbalance is mostly unknown.

One such unbalance is the hormones of the adrenal glands, that lie near the small of the back, and sometimes cause women to grow beards In experiments with mice, these adrenal hormones are known to be directly involved with the onset of one type of mouse cancer

Radioactive tracer studies in animals are likely to be as useful as in man, not only for the health of the beasts, but for the production of better food

Animals will be used for much of the tracer work done for human benefit, and the tracers themselves will be harmless to the animals Plants will serve as guinea pigs to some extent. Tracer work in them will be useful to agriculture, and for the discovery of new plant drugs and the improvement of old plant drugs More nutritious plant foods may be another tracer goal.

One of the mysteries of penicillin and the sulfa drugs may be clarified by tracers from the nuclear ovens. Scientists know how both of these drugs act in test tubes. They know also that the action is not the same in living tissues Apparently both drugs form combinations with some chemical compound already present in a living body This combination seems to account for the remarkably fast curative effects

Almost completely unknown are the reasons for natural growth. Likewise mysterious are the mechanisms that stunt normal growth And why a thumb does not grow as big as a foot is still less understood. Other than the effects of time, the reasons for growing old are unknown Even the changes in nutrition in ageing are not clear The tracers used to study metabolism and nutrition are new tools for understanding both growth and ageing.

In fact, there is no illness or annoyance of mankind, from heart disease or infantile paralysis to baldness, greying hair or infertility, that can in advance be counted out from benefits of tracer investigation Some will fail to benefit but many biological and medical puzzles will be clarified

Beyond the uses of the rays in industry and in medicine there is still a broader field, namely as tools for investigating the structure of matter The results of that are unpredictable But they are worth while because in that field will come some of the fundamental discoveries of the future

TRAILING THE CONFLIGULATOR

WHILE the World War still was at its height the Security Department of the atomic bomb project was disturbed by an article that appeared in a Texas newspaper. It read like this:

> NEW AND TERRIBLE WEAPON FOR USE AGAINST JAPS HAS OUTER FLAGELLA BIFID AND ALSO PERCOPODS CHELATE
>
> A new and terrible weapon is to be turned against the Japs in the near future, the manager of the Du Pont nylon salt plant now under construction said yesterday.
>
> He recently made a tour of the company's Richland plant where the weapon is being made and is familiar with the details of the death-dealing apparatus.
>
> The plan has been in operation about two years, according to the manager, but only now can the story of the weapon be released.
>
> "Shortly after the war began," he said, "the entire production of the E. I. Du Pont de Nemours company was switched to materials vital to the war effort.
>
> "Of course, the company started making many things which were entirely new to us. Some of the things will be a great boon to the civilian after the war. We are even hoping we can find some peacetime use for our latest device, Configulator T-1."
>
> "Confligulator T-1 is the newest weapon ordnance has under consideration," he continued. "Tactical uses are still secret, but it can be safely said the art of warfare will be revolutionized by it.
>
> "Briefly and in nontechnical language, Confligulator T-1 is a combination of totalizer wheels arranged to be propelled through multiple predetermined circumferential superpositions and an intrinsically heterogenous precomputed taxonomy of abutments controlled by nonconsecutive monodromic sequences of denominational seriatim concatenation.
>
> "One subassembly consists of an alkalitrachyte with phenocrysts of anc thoclase and aegirite in a tarchytic to hyalopilitic groundness of alkali-feldspar laths and grains of pyroxene and amphibole. The monocarpidean macrurans have antennules with outer flagella bifid and percopods chelate."
>
> Aw, nuts—let's give the damn thing to the Japs!

Richland is the name of a small town near the atomic ovens in Washington. The Du Pont Company erected the plants there. Confligulator obviously was a joke, and so the investigation proved it to be But Confligulators and their like all had to be investigated, not so much on account of the danger of spies, as because they started people to talking.

Anything printed about secret weapons, even those reported from Germany by the war correspondents, started conversation in America These conversations frequently led to discussion of atomic bombs. This job that Security did of investigating even innocent conversations as much as possible was one of the reasons for success in keeping the atomic bomb secret Security investigated about 2500 cases of publication or conversation.

Without this secrecy, the Allies might have faced a different situation in atomic bomb progress in Germany. After the war a letter was found in Germany, mailed from a Teutonic research center to Hitler This letter indicated that German espionage on atomic projects in America had failed. It stated that although the Americans were working on an atomic project, the United States had not been able to get beyond the early stages.

Had Hitler possessed correct information, it is anybody's guess what Germany might have attempted But what happened in Japan is a good guide The Japanese had their own atomic project They calculated that it would not be possible to make an effective bomb This was an error in calculation The Japanese scientists thereupon dropped the bomb idea and concentrated on trying to make uranium a substitute for coal. The empire was short of fuel of all sorts The Japanese had barely more than twenty pounds of metallic uranium, but they were hunting for deposits in Manchuria and elsewhere

Their uranium laboratory had been destroyed by bombs some time before the end of the war. Nevertheless the day after Hiroshima received the first atomic bomb, Japanese scientists went to work again to see if they could make one.

TIGHT TALK KEEPS THE SECRET

THE F. B. I. cooperated with the Manhattan Engineer District. But the maintenance of secrecy and safety was principally the work of an under-cover army organization known as the Security Department. The personnel was about 450 men and 35 Wacs. They served under Colonel W. Budd Parsons, who in civil life was a Seattle manufacturer

Most of the men of this force went through the war without uniforms. They could not explain to their friends. Most of them were college graduates Many were professional men. They were picked for known qualifications. Some were doctors in physics or chemistry. Others had industrial investigation experience. Some worked in plants where they had to refuse promotion because of their under-cover responsibilities. Few could be promoted to the grade of officers, but many of them received technical ratings.

Among the investigations were fifteen hundred cases of loose talk. The agents tried to stop such talk without telling the real reasons to the speakers. Sometimes the speed with which they caught up with the talker had the desired effect.

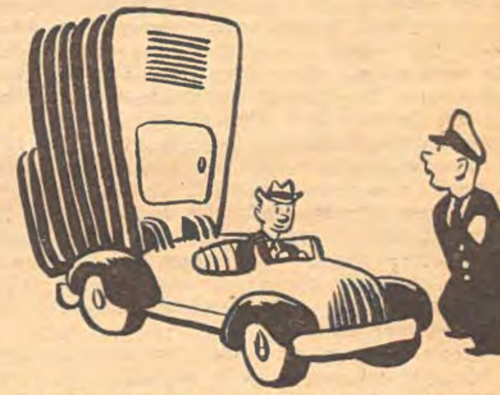
Persons who made a remark on a Wednesday about atomic energy were likely to be startled at a visit on a Saturday by an agent who said the

Limits of the Atom

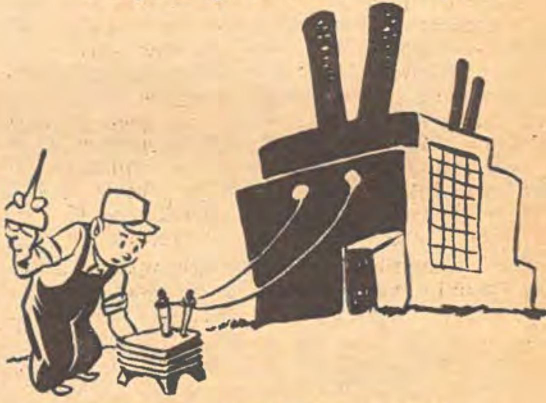
WHILE the harnessing of atomic energy opens great new fields for peacetime development, there are many things that atoms cannot do. For instance, atomic energy . . .

CAN'T substitute a block of uranium for the household furnace or kitchen range.

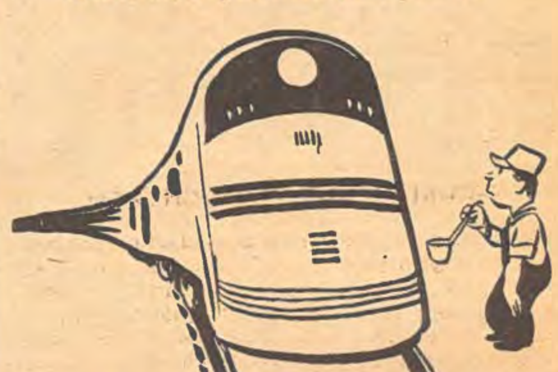
CAN'T change the cycle of the seasons.



CAN'T provide power for small cars, since 50 tons of shielding would be needed to protect passengers from deadly rays.



CAN'T make pea-sized power units.



CAN'T drive streamliners across the continent on a thimbleful of water.

ATOMIC ENERGY WILL SHAPE THE FUTURE OF THE WORLD

authorities would like to know the source of the conversation. Mostly the sources proved to be speculation. Sometimes agents learned what they wanted to know without revealing their identities.

Such a case concerned a waitress who had talked frequently about the routes of some truck drivers who made her lunch stand a regular stop. These drivers were atomic project men When an agent. in the guise of a customer, asked how she knew the routes, she pointed to the drivers' equipment for certain kinds of weather. She could, she said, put two and two together and figure where they went.

"Sure." said the agent. "But did you ever stop to think that if you put two and two together too often, you may get behind the eight ball?"

Bouncing putty, a new synthetic plastic that made its appearance a year before the war ended, caused one of the longer investigations. This one started when a young man living in the south called Dr Arthur H Compton in Chicago. long distance. and asked him for information about uranium 235 At that time Compton was supposed to be a complete secret so far as atomic energy was concerned Security agents learned that the young man was connected with a Farm Cooperative. and that as a side line he gave lectures on electricity. He got hold of a piece of bouncing putty and found it so fascinating that he got the idea of broadening his lecture subjects. In particular he wanted to add a lecture on another subject, the research on atomic bombs. The head of the Farm Cooperative knew Dr. Compton. The would-be lecturer got Compton's name, but not his address. He thought the doctor was in Kansas City. He tried to telephone the scientist in that city. and gave as an address a university that is not located in Kansas City. He put in a long distance call. The operator did the rest. She identified the right Compton and found him in Chicago.

A number of investigations were due to men seeking jobs, who wrote letters or sent telegrams asking for work connected with an atomic project in some city whose location was a secret for atomic purposes The explanations found in these cases usually were a long chain of tips, sometimes crossing the United States and back. passed along by one person to another. without any of the informants knowing about atomic bombs. But the last informant would innocently give the location of a city where he knew some men had been getting jobs. This last city would be the pipe line to an atomic bomb job

The Security Department read four hundred newspapers daily Hundreds of scientific publications and magazines were read and checked A number of young scientists received Ph.D. degrees on the basis of scientific papers they wrote. but which Security forbade to be published.

Security agents had to do much talking with draft boards. For there were 50,000 deferments on the atomic bomb projects. and no one could be told the real reason. The Manhattan District was one military organization that made good use of an enlisted man's previous qualifications. In this way about twenty-five hundred young chemists and physicists were obtained for the atomic projects.

An aid to secrecy was the innate good sense of Americans. Many men made shrewd guesses as to the nature of the work at Oak Ridge, Tennessee and elsewhere. But they kept their mouths shut. Oak Ridge workers, in response to questions as to what they were doing, sometimes made replies such as:

"This is something Eleanor thought up. It is something Franklin wants. We make the heads of horses to be sent to Washington to complete the animals."

These replies were not intended disrespectfully or politically, but as polite ways of getting over the idea that the job is "none of your business." Security and the great industrial organizations gave many carefully planned lectures and objective aids to employees, all based on patriotism and the need of keeping silent. These were given to more than 100,000 persons who might have access to enough unusual information to do some unwise talking The way these Americans cooperated was an example of democracy in action

SECURITY GOES TO CHURCH

EARLY in the war a religious publishing company issued a tract based on a sermon about the great things of life. Among these were startling powers. like the power of the universe typified by atomic energy. The author of the tract placed God above all these powers. One Sunday at church service an Illinois manufacturer picked up this tract. He took it home and read it. He got the idea that maybe here was something in industrial science and he wrote to the University of Chicago for information.

The same tract came up again as the source of information when a Knoxville pastor preached a sermon saying that the power of uranium 235 is the greatest thing man has discovered. But he added that this power cannot comfort man in his hour of trouble. Only God can do that. Security agreed that the sermon was splendid, but asked the minister not to repeat the uranium section. In Maryland another pastor preached a sermon enunciating the same principle and with the uranium from the tract as his source. This tract blazed a five-year long trail before the war ended

Poison ivy, cleaning acids, and heat rashes gave Security many headaches. Workers knew they were dealing with unusual compounds and that precautions were taken for their safety. Skin troubles alarmed them. Security had to deal with the skin rashes because an alarmed worker might talk One case of skin rash was followed to South America to make sure no atomic secrets were leaking. All sorts of precautions were taken for all phases of the atomic bomb work Waste baskets were collected daily under supervision of an armed guard and their contents were burned with the guard still watching. Used typewriter ribbons were destroyed because a spy might be able to read a few words on them

The briefcases of scientists and the representatives of industry on the job were objects of solicitude. The cases sometimes contained clues to atomic secrets. There are stories that the bodyguards, who were regularly assigned to the principal scientists were there primarily to prevent absent-minded loss of briefcases. The fact is that business men forgot briefcases too.

A high point in briefcase etiquette was inaugurated one day by a scientist He was making a trip accompanied by his bodyguard With them went a technologist from an atomic laboratory The scientist and the technologist each had a briefcase

The rules required the guard to carry the briefcases of scientists. On this trip the guard could carry only one briefcase. because another rule that was seldom if ever broken required the guard to keep one hand free to use his gun None of the trio knew what was in the technologist's briefcase The contents might include secret documents. The dilemma was solved by the scientist giving his own case to the guard, and himself carrying the case of the technologist, who was left with nothing to carry

Many incidents of keeping the secrets of atomic bombs made laughable stories afterwards But the precautions brought success beyond expectations There never was any known attempt at sabotage of the atomic projects by enemy agents. although there were a few cases of minor sabotage due to personal quarrels among the working forces There were attempts at espionage during the war These attempts continued at least for a time after the war ended But enemies did not profit by them.

THE SCIENTISTS SPEAK

PEACE or suicide are the alternatives frequently presented as the only choice offered civilization in dealing with the atomic bomb And new horrors are predicted

The horrors probably will come true, at least in possibilities. But the suicide may be doubted. Men always have been able to commit suicide individually. Few did so. Now there is the ability to commit universal suicide. But it is unlikely that men will do so, any more than most of them will kill themselves individually.

Two months after war ended in the Pacific scientists, most of whom never before had stepped out of their own fields, began speaking through newspapers, magazines, radio, lectures, and Congress They had several important messages for the public But they concentrated mostly on one of these. That message was the horrors. They did this because the public did not fully realize the tremendous forces discovered, nor the ease with which these forces could be used for destruction. These scientists believed that the best way to avoid the perils was to make it clear that the horrors surpass anything that has been imagined.

Almost without exception they offered a general principle of action. This principle was abolition of war. To this end they proposed international agreements, and many of them said the nations would have to give up some sovereignty.

Whether nations will choose to fight another war using atomic bombs is unpredictable. How war may be changed is also unpredictable. But Professor Niels Bohr, of Copenhagen, the father of the idea that an atom is a small solar system, stated a principle that is certain to apply, both to wars of the future, and to maintaining peace if wars are abolished.

"We have," he said, "even reached the stage where the degree of security offered to the citizens of a nation by collective defense measures is entirely insufficient."

Another principle, which defines the goal that in the end will be inevitable, was stated by Dr Arthur H. Compton, who now is Chancellor of Washington University, St. Louis. He said:

"The release of atomic energy is merely the most recent important step of that steady progression that is compelling man to become human"

There has been unanimous agreement by scientists, industry and the military authorities that other nations can make atomic bombs The only differences of opinion have been as to how long this will take in other countries. The disagreements were wide, running from two years to more than twenty. In reality two years or twenty makes little difference. Twenty years is only a brief moment in the face of the certainty that everyone who wants the bombs may have them.

But no scientist, industrialist or military authority believed that America's initial methods would remain unchanged. Here again there was wide difference in opinions. These ranged from the belief that atomic energies, whether for bombs or power, will be difficult to attain, anywhere, for at least ten or fifteen years, to discussions of "kitchen sink" methods of making atomic bombs "Kitchen sink" means almost literally that—that it can be done secretly in a house. There are now no such methods. Probably no one believes there ever will be any atomic power that can be produced in the kitchen sink. But there is no doubt whatever that at some unpredictable date, much easier methods of making atomic bombs will be perfected. In the long run, this attainment cannot be prevented even though attempts are made to curb the progress of bombs

This prospect of future bombs is one reason why many scientists, as well as others familiar with atomic energy possibilities, have taken the stand that agreement to stop making atomic bombs would be risking the destruction of the United States. Agreement to stop would result merely in making it possible for some ambitious nation to develop bombs with the hope of gaining mastery of the world

THE ONE WAY OUT

THE United States appears to have the choice of ending wars, or to change its character and become aggressive, in order to survive. There is no sign that Americans intend to change their character. All signs since the war point just the other way.

If the nations fail to abolish war, then Americans have to think about reverting to environments that were left behind with the cave man and medieval castles. People who want a measure of safety from atomic bombs will not live on stately hilltops, as did the medieval barons. They will hide their homes behind hills, and the more hills the better. They will have caves into which they can take their women and children. The United States is more vulnerable to atomic bombs than some of the other great nations, because of her great development of cities and concentration of industry in or near them.

There is no present sign that Americans will take to the hills. That is contrary to American character.

The hope that science in the future will find an effective defense against atomic bombs is not well founded. The bomb is simply a collection of metal. This metal does not deteriorate for practical purposes. Plutonium, it is true, deteriorates in 24,000 years. The stuff explodes automatically merely on being brought together No principles of nature are known to stop this explosion

Armies, navies, air fleets, pilotless ships, rocket weapons and even radar control as far as the moon, offer no complete defense Whether such defenses will be effective will depend on many things, including luck, politics and preparedness. There will be chances that they fail, with national destruction the penalty

Whatever angle of approach is chosen in atomic bomb discussions, at the end of the argument the one way out appears to be abolition of war No one has a sure formula for that

No matter what happens, the best guarantee of the future of the United States is a great, free, peacetime atomic energy industry. If war comes, only this peacetime industrial potential can make the speedy conversion that will be essential for atomic defense. This atomic potential will furnish the same sort of protection as did the industrial power of the United States in 1941.

1894—52—1946

YEARS of PROGRESS

FINANCIAL STATEMENT

December 31, 1945

ASSETS

Cash	$1,263,660.90
U. S. Government Bonds	3,485,924.63
Municipal Bonds	53,447.55
Railroad Bonds	78,460.25
Utility Bonds	77,379.15
Miscellaneous Bonds	56,719.84
Stocks	2,629,900.00
Premiums in Course of Collection	788,778.56
Real Estate	None
Due from Reinsuring Companies, Special Deposits and Miscellaneous	241,656.14
	8,675,927.02

LIABILITIES

Reserve for Claims	$1,706,522.98
Reserve for Unearned Premiums	1,684,368.03
Reinsurance Company Balances	410,438.14
Reserve for Commissions, Accounts Payable, etc.	203,505.82
Reserve for Premium Tax	184,511.29
Reserve for Federal Income Tax	325,000.00
Miscellaneous	47,365.47
	$4,561,711.73
Voluntary Contingency Reserve	614,215.29
Capital Stock	1,500,000.00
Surplus	2,000,000.00
	$8,675,927.02

Claims Paid to Date Over $36,000,000

Gross Premium Written During 1945, $9,997,991.56

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DETROIT, MICHIGAN

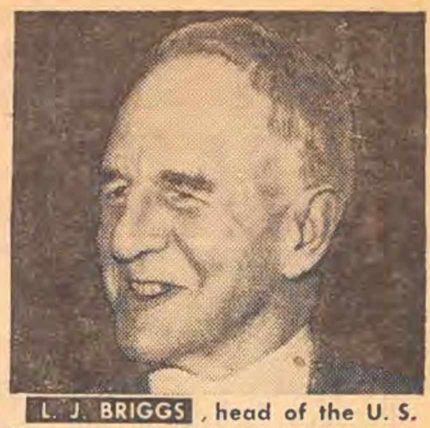
W. G. CURTIS, President

SOME OF THE ATOMIC PIONEERS

R. F. BACHER of the Massachusetts Institute of Technology had a big role in making the atomic bomb. His specialty is atomic structure.

KENNETH T. BAINBRIDGE of Harvard worked on the bomb. He specializes on electromagnetic forces and the weighing of atoms.

GREGORY BREIT of the U. of Wisconsin is a theoretical physicist. He calculated the force that is present in the nucleus of the atom.


L. J. BRIGGS, head of the U. S. Bureau of Standards, insisted on continuing bomb research after some said it would take too long.

VANNEVAR BUSH, president of Carnegie Institution, headed U. S. scientific war work and encouraged the early research on the bomb.

A. H. COMPTON, a Nobel winner who is now chancellor of Washington U., sponsored the work on plutonium for Chicago U.

J. B. CONANT, president of Harvard University, had an administrative role. He is a chemist, noted for his studies of chlorophyll.

JOHN R. DUNNING of Columbia was active from 1939 throughout in the discovery of uranium's qualities and in its production.

ENRICO FERMI, a former Italian, is a research wizard. First to bombard uranium with slow neutrons, he made the first atomic fire.

GENERAL LESLIE R. GROVES was the head of the bomb project. He supervised plant construction, operation and the scientists' work.

J. W. KENNEDY of the University of California, hardly known nationally before the war, is a chemist who helped on the bomb.

E. O. LAWRENCE contributed to the development of magnets that separated uranium. He also was an administrator in the bomb project.

J. R. OPPENHEIMER headed the Los Alamos New Mexico plant and laboratories that made the bombs. He is an administrator-scientist.

GEORGE B. PEGRAM made some of the early moves to interest the U. S. in atomic bombs. He knew of Germany's work on the atom.

G. T. SEABORG of the U. of California is a chemist, radiologist and has the unique position of co-discoverer of four synthetic metals.

HAROLD C. UREY, a Nobel Prize recipient, headed research done at Columbia to extract U-235 by the gaseous diffusion method.

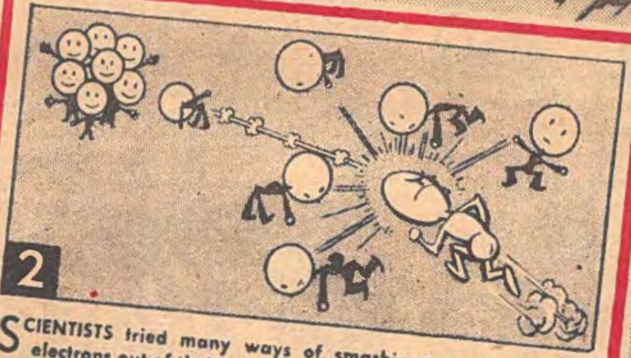
HENRY T. WENSEL, a physicist, became chief of the research control division of the Manhattan Engineering District at Oak Ridge.

EUGENE WIGNER of Princeton is a theoretical physicist, born in Budapest, who has made studies on the structure of the nucleus.

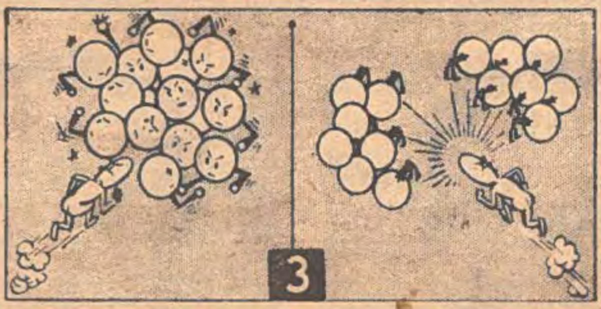
ATOMIC PRIMER

LIKE our solar system, an atom is made up of a central sun (nucleus) around which one or more planets (electrons) rotate. Protons (positive electric charges) in the nucleus hold electrons (negative electrically) from flying out of orbits.

The number of electrons in natural atoms range from 1 to 92 and determine what the substance is: gold, lead, uranium, etc. A nucleus also contains neutrons, which have neither a positive nor negative electrical charge. But keep your eye on the neutron. They are the key to the mystery of the atomic universes which are so small that millions of them are needed to make a speck of matter



SCIENTISTS tried many ways of smashing atoms. Knocking electrons out of their orbits was easy but the energy released was small compared to what could be done if the nucleus, which contained nearly all the mass of the atom, could be split. In 1932 the neutron was discovered and in 1939 it was found that a neutron, fired like a bullet, could split the nuclei of some atoms. In some other atoms it would lodge in the undivided nuclei and start a remarkable chain of events. When nuclei in the first type of atom fly apart, they give off blasts of energy like toy balloons popped by a pin, but the atomic force is billions of times greater.



EXPERIMENTS disclosed that different atoms, like people, react in various ways when shot at. If a neutron hits the nucleus of that type of uranium which has 143 neutrons in its nucleus in addition to 92 protons (U-235), the nucleus splits and releases energy. If the external neutron hits a uranium nucleus that contains 146 neutrons in addition to 92 protons (U-238), the nucleus doesn't split but instead absorbs the neutron. The atom's weight is increased from 238 to 239, and then, in a mysterious series of processes, the atom changes into two new elements, first neptunium and then plutonium. Further, it was found that the final plutonium was just as nervous and as readily split as U-235 if it was hit with a neutron bullet.

AFTER scientists found the atomic bullet they learned that if it was fired too rapidly it had less effect on nervous nuclei than one moving at a slower speed. (Neutrons can travel at a speed of several thousand miles per second.) They learned that if islands of uranium were placed in graphite or heavy water, the neutron lost just enough speed by the time it reached another uranium island to have the desired effect of splitting U-235 nuclei. The newly split nucleus emits several neutrons, some of which hit other U-235 atoms to continue the splitting process, while the rest hit U-238 and converted it into plutonium. The graphite or heavy water slow-down cops are called moderators.

BECAUSE U-235 (the type of uranium which man found gives off atomic energy most readily) is only seven-tenths of one per cent of ordinary uranium, U. S. scientists developed huge centers for concentrating usable quantities of the element. In one process, uranium gas is forced through strainers that pass U-235 more rapidly than the ordinary U-238. In a magnetic process, U-235 is trapped because its atoms curve through the electric field in a different manner than U-238. A third process obtains the element by diffusion in a liquid. The processes involve thousands of steps before workable amounts are obtained. The atomic bomb puts together facts described in this "Atomic Primer" series. A gun fires masses of uranium together and an explosion follows, with nearly all the atoms splitting in one-tenth of one millionth of one second.